Patterns of Stent Purchasing in a Collaborative Procurement Organisation

by

Joseph David James McCabe

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

University of Warwick, Warwick Business School

December 2010

Table of Contents

Table of Figures

Table of Tables

Acknowledgements

I give thanks to God whose grace and blessings have sustained me through the highs and lows of this long journey.

I would like to acknowledge the assistance and support provided by my supervisors, Dr Scott Dacko and Professor Philip Stern. Their advice has often been challenging but always valuable and rewarding. I thank both of them for their confidence, their unwavering patience and their generosity with their time and knowledge.

This research has depended on access to data within the National Health Service. I am indebted to Samantha Forrest and Darren McVee and their colleagues in the NHS for their assistance in securing access and in acquiring the necessary data for the research, without which the research would not have been possible.

My family has been a constant support throughout the PhD process, in particular my wife Ann. Her love and friendship have been unceasing and her encouragement has helped me through to completion of my PhD. My two daughters, Sophie and Rebecca, have been more patient than I could ever have imagined and I look forward to spending more time with them. I would also like to thank my sister-in-law, Linda, whose typing skills have been most helpful. Finally I would like to thank my mother Lorna, who has always encouraged and supported me in whatever I have done.

This thesis is dedicated to the memory of my father, Harry McCabe.

Declaration

This is to declare that:

- I am responsible for the work submitted in this thesis.
- This work has been written by me.
- All verbatim extracts have been distinguished and sources specifically acknowledged.
- During the preparation of this thesis, two conference presentations and one journal paper were prepared as listed below. The remaining parts of the thesis are unpublished.

McCabe, J., (2006), 'Capital Equipment Purchasing: A Stochastic Model of Industrial Buying Behavior', Presented at the Doctoral Colloquium of the Annual Conference of the Academy of Marketing Science, San Antonio TX, 2006.

McCabe, J., (2006), 'Stochastic Modelling and Industrial Networks – Complementary Views of Organisational Buyer Behaviour', Presented at the Doctoral Colloquium of the Annual Conference of the Academy of Marketing, London, 2006.

McCabe, J. and Stern, P., (2009), 'Stochastic Modelling and Industrial Networks - Complementary Views of Organisational Buyer Behavior', *Journal of the Academy of Marketing Science*, 37 (2): 204-214.

- This work has not previously been submitted within a degree programme at this or any other institution.

Signature: _____ Date: _____

Abstract

Leveraging purchasing power through collaborative purchasing arrangements is widely used to deliver efficiency savings in public procurement. The success of such arrangements requires the purchasing behaviours of individual members of the collaborative organisation to change in order to realise the benefits of lower prices. However the actual purchasing behaviours of organisations within a collaborative purchasing arrangement have not been widely researched.

The research uses a stationary stochastic model of buyer behaviour, the NBD-Dirichlet, to describe and predict the purchasing behaviours of buyers of coronary and ureteral stents in a collaborative purchasing organisation in the English National Health Service. The three year analysis period is a period of major change for each category, the result of supplier promotional activity in the ureteral stent case and purchasing management activity in the case of the coronary stents.

Deviations between the observed patterns of behaviour and the model predictions point to violations of the basic Dirichlet requirements of stationary markets and lack of partitioning. In both the ureteral and coronary stent cases the research identifies a segment of frequent purchasers whose behaviour differs from the rest of the population. The impact of framework agreements in restricting the purchasing repertoire of buyers is also identified as a deviation from typical purchasing patterns.

Both interventions result in changes to established loyalty patterns, whereby the initial high observed levels of loyalty towards particular suppliers are replaced by a greater willingness to purchase from alternative suppliers. The data analysis also provides preliminary evidence for purchase deceleration as buyers defer purchases during a negotiation period in anticipation of improved pricing.

Keywords: NBD-Dirichlet, Collaborative Purchasing, Purchasing Consortia, Loyalty, Organisational Buyer Behaviour

1 Introduction

1.1 Overview

This research aims to describe, model and predict purchasing behaviours of member organisations in a collaborative public procurement environment. Collaborative procurement is seen by governments as a way of reducing purchase costs and delivering value for taxpayer's money. Increased supplier leverage results in price reductions and transaction costs can be reduced by pooling resources. However these cost savings usually decline year on year as the opportunities for improvement diminish (Johnson, 1999). The delivery of further savings requires product standardisation and vendor rationalisation (Chapman et al, 1998), and for purchasers to change their behaviours concerning supplier choice.

The importance of purchasing behaviour in achieving the goals of collaborative procurement indicates a need for further research in this area. The collaborative procurement literature is focused on describing, defining and theoretically modelling cooperative purchasing. It addresses the motivation for collaboration, the structures of collaborative procurement organisations, the evolution of these structures and the conditions for successful collaborative procurement. However there is a relative lack of research into how member organisations in collaborative purchasing arrangements actually purchase and the effect of membership of a purchasing group on members' purchasing behaviours, in particular patterns of supplier loyalty.

This research therefore seeks to identify to what extent members of collaborative procurement organisations exhibit regular patterns of buyer behaviour. An established steady state stochastic model of consumer buyer behaviour, the NBD-Dirichlet, is used to describe and predict the observed buyer behaviour in order to assess the impact of collaborative purchasing arrangements on the buying behaviour of member organisations.

1.2 Background to the Research

"*Collaboration and saving taxpayer's money has never been so important. The current economic climate means that public spending is coming under increased pressure and scrutiny with all parts of the public sector expected to work together and contribute to significant procurement savings now and in the future.*"

(Office of Government Commerce, 2010)

Collaborative procurement is seen by central government as a key mechanism to achieve efficiency targets (Gershon, 2004; Bakker & Walker, 2008). Aggregating demand to increase purchased volumes can improve leverage with suppliers and deliver short term price reductions as well as reducing transaction costs by pooling supplier management activities. Members of collaborative procurement organisations also gain access to resources and capability that they may not be able to access on their own and also benefit from improved marketplace information (Essig, 2000; Bakker et al, 2006a). Financial savings of up to 20% per year through transaction cost reductions, access to expertise and leveraging demand have been reported from English local government councils coming together to share purchasing resources (Murray et al, 2008).

Delivered cost savings tend to decline as the procurement organisation matures and the opportunities for supplier leverage diminish (Johnson, 1999). Longer term savings require buyers to change their purchase behaviours in order to benefit from supplier rationalisation and product standardisation (Chapman et al, 1998). As the managing director of a purchasing consortium notes "Most people who do joint purchasing focus too much on negotiating discounts. They need to control the whole process and concentrate on behaviour management … otherwise we cannot move purchases from one vendor to another" (reported in Cohen, 2002, p.29).

Much of the research into collaborative purchasing organisations has attempted "to explain, predict and understand behaviour concerning the intent, purpose and actual use of cooperatives in procurement" (McCue & Prier, 2006, p. 46). The literature addresses why organisations pool their purchasing requirements, how they pool these requirements (the structure and form of purchasing consortia), how these consortia develop and the factors critical to the successful implementation of collaborative procurement. Among the critical success factors are the commitment and compliance of member organisations to the requirements of the collaborative organisation, usually in terms of enforced contracts involving minimum spend targets with particular suppliers. Failure to comply with these targets can result in the imposition of punitive penalties (Elhauge, 2002; Nollet & Beaulieu, 2005).

When the control of member behaviours is not coercive but relies on the commitment of the members, the challenge for the purchasing manager is to overcome the established purchase loyalty patterns by introducing and

encouraging the use of new or alternative suppliers or discouraging the use of others. To do this effectively, they need to understand the buying behaviours of the member organisations in order to identify current loyalty patterns. For example, a high incidence of members buying from a single supplier, so-called sole loyalty, can result in a localised lack of competition such that suppliers may become complacent and there is an increased risk of supply chain disruption. An understanding of the current behavioural patterns can help the purchasing manager to determine to what extent buyer behaviour can be changed, to design intervention strategies and to ensure the sustainability of such interventions by monitoring progress and compliance.

There has been no research into purchasers' buying behaviour in collaborative procurement organisations, either to establish whether any regular patterns can be identified or to assess any changes in behaviour before and after a purchasing invention, for example a supplier development initiative or implementation of preferred supplier framework agreements. It is against this background that the aims and objectives of the research were developed.

1.3 Objectives of the Research

This research addresses the gap in the purchasing literature by analysing and modelling purchase behaviours in a collaborative procurement organisation. The research has three main objectives:

i. To determine if organisational buyers in a collaborative purchasing organisation exhibit regular patterns of purchase behaviour in terms of purchase incidence and supplier choice,

ii. If such patterns exist, to model the observed behaviours using an established model of buyer behaviour, the NBD-Dirichlet and to use this model to assess the impact of the collaborative purchasing arrangements on observed buyer behaviours,

iii. To provide purchasing managers with metrics and benchmarks to assess and monitor buyer behaviour.

1.4 Contribution of the Research

The collaborative purchasing literature is mainly concerned with the motivation for the use of collaborative purchasing arrangements (Tella & Virolainen, 2005), the structure and form of purchasing consortia (Bakker et al, 2006a), the evolution of collaborative purchasing organisations (Laing & Cotton, 1997) and the critical success factors that influence the successful implementation of collaborative procurement (Schotanus et al, 2010). However there is a lack of research that describes and explains how organisations in collaborative purchasing groups actually behave.

In addition, the NBD-Dirichlet literature has primarily been concerned with fast moving consumer goods with few applications in organisational purchasing behaviour (Uncles & Ehrenberg, 1990; Bowman & Lele-Pingle, 1997; Pickford & Goodhardt, 2000). Although concerned with buying behaviour in organisations, these studies have all featured independent organisations that are not operating within the constraints of a collaborative purchasing framework.

This research contributes to the understanding of organisational markets by describing and explaining patterns of purchasing behaviour in a collaborative public procurement organisation. It is also is the first time that the NBD-

Dirichlet has been used in a purchasing and supply chain context. The impact of framework agreements on restricting buyer purchasing repertoires and in changing established loyalty patterns is observed and discussed.

The research is a substantial extension of the NBD-Dirichlet model into a new situation. The complex conditions of collaborative public procurement in a regulated surgical supplies market represent a differentiated replication, further extending the generalisability of the NBD-Dirichlet model of buyer behaviour.

The research also makes a contribution to marketing and purchasing theory by arguing that stochastic modelling of buyer behaviour and the markets-as-networks tradition of the Industrial Marketing and Purchasing (IMP) group of researchers have much in common and can be complementary approaches to the study of organisational marketing and purchasing behaviour.

For marketing and purchasing professionals, the research provides an understanding of public procurement market structures. The model provides norms and benchmarks of such measures as the extent of sole loyalty (the proportion of purchasers who use one supplier only) and the rate that these solely loyal purchasers actually buy. Such benchmarks can be used to assess the effectiveness of procurement policies, for example the implementation of framework agreements, supplier development or supplier rationalisation. Loyalty metrics such as Share of Category Requirements can highlight the extent of supplier competition and identify if any suppliers are enjoying "excess" loyalty. If preferred supplier or framework agreements are implemented, the same loyalty measures can be monitored to see if the interventions are having any effect. By detailing which alternative suppliers are

used by purchasers of a particular supplier (using duplication of purchase tabulations), credible alternatives can be identified for supplier development. By the same token highly duplicated suppliers which are purchased mainly by buyers who fulfil most of their category requirements with other suppliers are potential candidates for supplier rationalisation.

1.5 Research Questions

The objectives of the research give rise to three research questions:

i. Do organisational buyers in a collaborative purchasing organisation exhibit regular patterns of purchase behaviour in terms of purchase incidence and supplier choice?

ii. Can the NBD-Dirichlet accurately describe and predict the observed purchasing behaviours?

iii. Can the NBD-Dirichlet theoretical predictions provide benchmarks for purchasing managers to assess and monitor interventions to bring about sustainable changes in buyer behaviour?

1.6 Methodology

The research is a differentiated replication of the NBD-Dirichlet model of buyer behaviour. Under the Empirical then Theoretical (EtT) approach, empirical regularities or patterns prompt the establishment of empirically grounded theory. The theory is tested more widely under different conditions to extend its generalisability and develop it conceptually (Ehrenberg, 1994). Previous research has located the epistemology of replication and empirical generalisation as a Lakatosian research programme (Stern, 1994), based on sophisticated methodological falsification within the research programme (Lakatos, 1978).

Sophisticated methodological falsification holds that empirical testing alone is necessary but not sufficient for the refutation of a theory. Falsification can only occur with the emergence of better theories. Research within the research programme thus proceeds according to a "positive heuristic", a set of guiding research questions and theoretical forms. Within the research programme, theories can be disproved but not proved and the refutation of a single theory is not sufficient for rejection of the entire programme. The Lakatosian perspective recognises that science is a creative process, occurring within the context of a research programme established by the norms, beliefs and values of the scientific community. It demands consistency within the guiding principles of the research programme as a means of preserving scientific rationality although it makes no claim for the objectivity or "truth" of science.

In the EtT approach (Ehrenberg, 1994) theory is tested more widely under different conditions to extend the generalisability of the theory and develop it conceptually. The cycle of replication and conceptual theory development creates the "guiding questions" that shape a positive heuristic in a Lakatosian research programme. The theory is judged not by how well it fits a single instance but by how generalisable it is over a range of different circumstances (Ehrenberg, 1995). The essence of replication is to find "significant sameness" across many sets of data, preferably covering a wide range of conditions (Barwise, 1995). Conditions that are not described by the theory do not represent a refutation of the theory but rather establish boundary conditions for application of the theory. If such situations are repeatable then new theory may be developed to address the new conditions.

Data for the current research is collected from a Collaborative Purchasing Hub in the English National Health Service (NHS). Collaborative procurement is relatively mature in the NHS and aggregation of data from individual purchasing organisations is well established. Exploratory discussions and analysis of pilot data from a single NHS hospital trust identified coronary stents as a suitable category for analysis. Coronary stents represent a significant expenditure for the NHS and have been the subject of purchasing interventions in both the single trust and the collaborative hub. The pilot study also established data requirements and data availability for the research and served to test proof of principle for the subsequent longitudinal study. This covers a three year period during which a set of framework agreements for coronary stent supply were discussed, negotiated and implemented. The dynamic development of the market structure during this period is observed and modelled. Purchasing patterns for ureteral stents are also analysed. This category has not been the subject of any purchasing interventions and acts as a control against which to compare performance in the coronary stent category.

The research employs an established stationary model of buyer behaviour, the NBD-Dirichlet to describe and predict the observed patterns of purchasing behaviour. By building on theory that is already proven, the research contributes to the Dirichlet research programme and is more likely to generate findings that are generalisable over a range of purchasing situations and purchase categories than an isolated study that is specific to a single data set. The NBD-Dirichlet is an extremely parsimonious model, requiring only data that is readily available from purchase order or accounts payable systems. Although a steady state model, the Dirichlet is used to analyse dynamic conditions through a series of

snapshots that track the changes in purchasing patterns over a period of time. The method used to determine the Dirichlet parameters follows the method set out in Ehrenberg (1988) and Goodhardt et al (1984) and coded in the BUYER software package (Uncles, 1989).

Interviews are conducted with two purchasing professionals involved in the coronary stent intervention in order to share the findings of the statistical analysis and to confirm the observed purchasing patterns. The interviews provide context and background to aid the interpretation of the observed purchasing patterns.

1.7 Structure of the Thesis

The thesis is divided into eight chapters with supporting appendices and references. Chapter 1 discusses the background to the research, its aims and objectives and its contribution to theory and practice.

Chapter 2 reviews the extant literature in organisational marketing and purchasing, in particular that which considers purchasing in collaborative procurement organisations and conceptualisations of purchasing behaviour and loyalty. These include relational models such as the IMP approach, econometric models and stochastic models such as the NBD-Dirichlet. The generalisability, practical use and track record of the methods are compared.

The methodology for the research is developed in Chapter 3. This discusses the epistemological approach for the research. The chapter proceeds to describe the data required for the analysis, the data sources and the methods used to analyse the data. The methods for determining the parameters of the NBD-Dirichlet

model, the use of the model to predict repeat purchasing behaviour patterns and the goodness of fit tests used to assess the fit of the predicted behaviours to the observed behaviours are discussed. The pilot data is used in worked examples to demonstrate the operationalisation of the NBD-Dirichlet model.

Chapter 4 describes the purchasing organisation in the NHS and the role of the Collaborative Purchasing Hub in delivering best value in purchasing for the trusts within it. The chapter highlights the tensions that exist between the design and specification of clinical solutions and their sourcing. It explains why stent purchases within the NHS is a suitable case to analyse in the context of the research objectives

Chapter 5 presents the results of the pilot study carried out on data collected from a single NHS hospital trust. The chapter presents a description of the data, the fitting of the model and the use of the model to predict purchasing behaviour in subsequent periods. The analysis shows that even with a relatively short analysis period, the NBD-Dirichlet describes supplier performance measures such as penetration, purchase frequency and share of category requirements with good accuracy. A heavy (high frequency) purchasing segment is identified and shown to purchase from a restricted set of suppliers, demonstrating the operation of preferred supplier framework agreements. The pilot study identifies coronary stents as a suitable category for analysis and demonstrates that stent purchasing patterns in a single hospital over a limited time period can be modelled using the NBD-Dirichlet. This provides a sound basis for extension of the analysis to the more complex longitudinal study of the purchasing patterns in the collaborative purchasing hub.

Chapter 6 deals with a longitudinal analysis of ureteral stent purchases in a collaborative procurement hub. This category has had no purchasing management intervention and provides an opportunity to compare performance against the coronary stent category which has had some intervention. A description of the data set is followed by the parameterisation of the model and testing for goodness of fit. It is shown that the NBD-Dirichlet is able to satisfactorily describe and predict the observed purchasing behaviours. The model provides behaviour benchmarks against which the observed behaviours are assessed. There is a major change in the relative market positions of the two dominant suppliers during the analysis period, a change attributed to supplier activity. Deviations between the observed behavioural patterns and those predicted by the model are explained by the existence of a high purchase frequency (heavy purchasers) segment and a low purchase frequency segment (light purchasers) with distinctive and different purchasing behaviours.

Chapter 7 presents and discusses the analysis of the coronary stent category. The 2006 – 2008 data set covers the formalisation of a major purchasing intervention in a negotiated set of framework agreements in September 2008. It is shown that the NBD-Dirichlet can provide satisfactory predictions of observed purchasing behaviour, including a change in loyalty behaviours immediately after implementation of the framework agreements. A marked reduction in purchase activity during the period immediately preceding the implementation of the frameworks is observed and may be evidence of inventory reduction before more attractive pricing comes into force.

Chapter 8 draws together the findings of the research and reviews to what extent the research questions have been met. The chapter presents the theoretical contributions of the research and discusses the managerial implications of the findings. The limitations of the research and recommendations for future research are discussed.

The thesis concludes with the presentation of the appendices and references. Appendix A contains a methodological paper published during the research, "Stochastic modelling and industrial networks - complementary views of organisational buyer behaviour". Appendix B presents a summary of the abbreviations and notation used throughout the thesis.

The next chapter considers the extant literature in organisational marketing and purchasing, including purchasing in collaborative procurement organisations and conceptualisations of purchasing behaviour and loyalty.

2 Buying Behaviour in Collaborative Procurement Organisations

2.1 Introduction

Recent years have seen a marked increase in the attention given to collaborative or cooperative purchasing arrangements in the purchasing and supply literature. Much of this literature has set out to describe, define and theoretically model cooperative purchasing – "to explain, predict and understand behaviour concerning the intent, purpose and actual use of cooperatives in procurement" (McCue & Prier, 2006, p. 46). The literature addresses the motivation for the use of collaborative purchasing arrangements, the structure and form of purchasing consortia, the evolutionary development of such consortia and factors critical to the successful implementation of collaborative procurement.

While aggregated demand can increase leverage with suppliers and deliver short term price reductions, longer term savings will accrue from supplier rationalisation and product standardisation (Chapman et al, 1998). This requires less focus on negotiating discounts and more focus on behaviour management in order to change the current patterns of supplier choice and get best value from any negotiated purchase frameworks (reported in Cohen, 2002, p.29).

Even the savings from aggregated demand can be lost if members of the purchasing group fail to purchase contracted volumes from particular suppliers (Doucette, 1997). Compliance, commitment and effective monitoring are identified as success factors for collaborative purchasing organisations

(Doucette, 1997; Rokkan & Buvik, 2003; Harland et al, 2007), yet nothing in the collaborative purchasing literature addresses the way in which member organisations actually purchase and how their purchasing behaviours change when they respond to procurement initiatives within a purchasing consortium.

There is however a wide body of organisational buying behaviour literature in both the purchasing and supply chain literature and the marketing literature that does provide insights into purchasing behaviours and in particular the notion of supplier loyalty. Compliance within a collaborative purchasing organisation means loyalty to the group rather than a particular supplier. The extent to which member organisations stay loyal to their incumbent suppliers rather than adopting new suppliers promoted by the consortium should be a measure of success for the collaborative procurement organisation.

The literature review will proceed with an overview of the collaborative procurement literature in order to locate the research question within the knowledge base. A brief overview of concepts of loyalty in organisational purchasing will follow. The literature relevant to loyalty and repeat purchasing in business markets will be discussed using the taxonomy proposed by Barclay (1992) which makes the distinction between research that focuses on a single (usually the buying) organisation and research that considers buyer/seller interactions. As can be seen in Figure 2.1 below, Barclay's second dimension considers organisational buying within either a single decision or a series of decisions.

		Organisational Focus: Intra	Organisational Focus: Inter
Decision Process Focus	Within a decision	A decision within the buying organisation (Cell 1)	A discrete buyer/seller transaction (Cell 2)
	Over a series of decisions	A series of related decisions within the buying organisation (Cell 3)	Buyer/seller relationship (Cell 4)

Figure 2.1 Taxonomy of organisation buying research (Barclay, 1992)

By definition, the analysis of repeat purchasing involves successive decision points. In this context the distinction between single decisions and a series of related decisions is less useful than the intra / inter dimension. The earliest models of organisational buyer behaviour recognised that even a single purchase event required multiple decisions to "identify, evaluate and choose" (Webster & Wind, 1972) and that the event would be influenced by the "satisfaction with past buying experiences" (Sheth, 1973).

Consequently the following discussion adopts the organisational focus dimension of this framework to present an overview of the organisational buying behaviour literature. In the "intra" category the review will consider how loyalty and repeat purchasing behaviour within purchasing organisations has been conceptualised. In the "inter" category the focus will be on the interactions between organisations and will consider the work of the Industrial Marketing and Purchasing (IMP) group as well as

the growing literature on relationship marketing and cooperative purchasing arrangements.

The review proceeds with a review of quantitative modelling approaches in buyer behaviour including econometric models of attitudinal and contingent loyalty and stochastic models of behavioural loyalty. This includes an extended review of the NBD-Dirichlet model of buyer behaviour.

The review of the literature will locate the research question within the existing knowledge base, showing how the research will contribute to the understanding of purchasing behaviours in collaborative purchasing organisations and to the broader buyer behaviour literature.

2.2 Collaborative Procurement

Collaborative procurement involves two or more organisations at the same or similar position in the supply chain, coming together, formally or informally, to aggregate purchasing volumes and share information or resources. The objective is to gain procurement advantages over and above those that could be obtained if each organisation acted alone (Hendrick, 1997; Schotanus & Telgen, 2007). Membership of a collaborative procurement organisation is typically expected to deliver improved effectiveness (enhanced capability through pooling of knowledge and access to resources) and improved efficiency (through increased leverage over suppliers, reduced transaction costs and better access to markets) (Tella & Virolainen, 2005; Bakker et al, 2006a). This approach should not be confused with the concept of the collaborative supply chain where the

collaboration is vertical (between buyer and supplier) rather than horizontal (between buyers) (Patterson et al, 1999).

Collaborative procurement arrangements (also referred to as cooperative purchasing, group purchasing, pooled purchasing or consortium purchasing) are particularly popular in the public sector (Essig, 2000) and have been used in UK local government since 1957 (Murray et al, 2008). In recent years their use has become more widespread, largely as a response to a central government efficiency review in which collaborative procurement is seen as a key mechanism to achieve efficiency targets (Gershon, 2004; Bakker & Walker, 2008). Although private sector purchasing consortia are becoming more important, participation rates among private sector companies are reported to be 25% or below (Hendrick, 1997; Vigoroso, 1998; Tella & Virolainen, 2005). The reluctance of the private sector to make more use of collaborative purchasing arrangements has been attributed to anti-trust issues, concerns over disclosure of confidential information and a perception that collaboration would not deliver any improvements to the firm's existing supplier agreements (Hendrick, 1997). In addition, public sector organisations do not generally compete with one another, there is often mutual trust and shared objectives, similar organisational culture and common external pressures, notably central government efficiency targets (Schotanus & Telgen, 2007).

Increased adoption of collaborative purchasing in practice has been accompanied by an increase in the academic literature on the use of collaborative purchasing groups. A theoretical framework has been developed, drawing on transaction cost economics, the resource based view of the firm,

agency theory, network theory and game theory (Schotanus & Telgen, 2007; Tella & Virolainen, 2005). Schotanus and Telgen (2007) present a comprehensive literature review of the field as part of their attempt to develop a typology for purchasing groups. They categorise collaborative procurement research in five areas:

- motivation (advantages and disadvantages of cooperative purchasing)
- forms of collaborative purchasing (coordination structure / typology)
- evolution (development) of purchasing groups over time
- critical success factors (enablers and barriers)
- formation of purchasing groups in electronic markets.

The literature includes interpretive and descriptive accounts of collaborative purchasing group formation and operation (Laing & Cotton, 1997) and normative models of optimum group structure based on a range of factors including member characteristics (range of sizes, geographical spread, homogeneity of requirements, procurement maturity), the size of the group (i.e. the number of members), the degree of maturity of the collaboration initiative and the intensity of cooperation and scope of group activities (Bakker et al, 2006a). Empirical research predominates, using both case study and survey methodologies to describe and explain cooperative procurement behaviour.

2.2.1 Motivation for Collaborative Purchasing

Cost savings are usually cited as the main motivation for joining a collaborative purchasing group although improved information about supply markets has also

been identified as a factor (Tella & Virolainen, 2005). Individual organisations that lack the knowledge, resources or capabilities to operate effectively in the supply market may collaborate to improve effectiveness (Bakker et al, 2006a).

Savings of between 10% and 30% are reported to be generated by purchasing groups (Hendrick, 1997; Vigoroso, 1998; Johnson, 1999; Nollet & Beaulieu, 2005) although very few studies report actual savings. Cost savings are delivered along the dimensions proposed by Anderson and Katz (1998) – "Buy for Less, Buy Better and Consume Better". "Buy for Less" savings (i.e. lower purchase prices) are achieved through aggregating purchases to realise economies of scale and increased leverage over suppliers. "Buy Better" savings result from reduced transaction costs as activities such as bidding, supplier evaluation, negotiation and contract management are carried out at group level rather than by individual buyers (Essig, 2000; Murray et al, 2008). In some cases reduced transaction costs have been delivered through staff reductions (Johnson, 1999). "Consume Better" savings are expected to come from supplier rationalisation and product standardisation. Although these factors can be more powerful than scale in delivering savings, they are problematic to deliver, especially in a healthcare context where clinicians have considerable power and autonomy in product specification and procurement decisions (Chapman et al, 1998; Cox et al, 2005). Restricting the autonomy of expert specifiers to choose suppliers requires a change in behaviours (Cohen, 2002) and for the members of the purchasing group to remain committed to the new behavioural patterns (Cleverley & Nutt, 1984; Doucette, 1997).

This commitment can be achieved through enforced contracts (Cleverley & Nutt, 1984), punitive penalties or forfeiture of loyalty rebates if members do not meet contracted minimum percentage performance targets, which may involve purchasing more than 90% of requirements for a category from a single supplier (Elhauge, 2002; Nollet & Beaulieu, 2003) or monitoring of compliance (Rokkan & Buvik, 2003). Maverick purchasing, opportunism and other forms of non-compliance are a problem in many collaborative purchasing agreements, particularly when the information infrastructure does not allow adequate monitoring (Harland et al, 2007).

As changes to purchasing patterns are important mechanisms in the delivery of sustainable cost savings from collaborative purchasing, it is important to understand how members purchase both before and after participation in a purchasing consortium. However, there has been no research into purchasing patterns in collaborative purchasing organisations to determine how members buy and what they buy, either to inform supply base interventions or to monitor the outcomes of such interventions.

2.2.2 Critical Success Factors for Collaborative Purchasing

The factors that contribute to successful collaborative purchasing arrangements include trust between the group members, formality of the group, uniformity of the group members, common objectives, communication between group members, enforcement of cooperation, influence of group members, allocation of gains and costs, cooperation of group members and commitment and internal support (Schotanus et al, 2010). In some studies these are identified as enablers or in the negative sense, barriers or constraints. While many of the factors

address issues such as governance, form, group dynamics and communications within the group, there is a strong thread of commitment, compliance, cohesion and trust – of loyalty to the group that transcends loyalty to a particular supplier or group of suppliers (Cleverley & Nutt, 1984; Doucette, 1997; Cohen, 2002; Nollet & Beaulieu, 2003; Rokkan & Buvik, 2003; Nollet & Beaulieu, 2005; Bakker & Walker, 2008).

There is an acknowledged lack of consensus as to what constitutes success in a purchasing group, with various measures such as longevity, contribution to the underlying competitive advantage of the member organisations or financial performance (Schotanus et al, 2010). In their study of critical success factors, Schotanus et al. (2010) use as a measure of success the extent to which members of the purchasing group perceive that their group is successful. Others measures of success employed include discounted cash flow (i.e. cost savings net of consortium costs) (Essig, 2000), cost savings and return on consortium "investment" (Hendrick, 1997) and price paid for products bought through the consortium (Cleverley & Nutt, 1984).

Following on from the previous section, if changes to purchasing behaviours are important elements in the sustainable delivery of cost savings, a further measure of success could be the extent to which the organisational purchasing patterns are changed as a result of the collaboration. As before, assessing the extent of the change requires an understanding of the members' purchasing behaviours, including supplier loyalty and how buyers spread their purchases of a category among the pool of suppliers. There has been no research conducted into how the

loyalty dynamics of particular markets operate in collaborative purchasing arrangements or how they change after entry into a purchasing consortium.

2.3 Concepts of Loyalty

"*What they call their loyalty, and their fidelity, I call either their lethargy of custom or their lack of imagination.*"

(Oscar Wilde, *The Picture of Dorian Gray*)

Jarvis and Wilcox (1977) echo Wilde when they draw a distinction between "true vendor loyalty" and "simply repeat purchase behaviour". In addition to issues of definition (loyalty to technology, product class, manufacturer's brand, distribution channel or individual) (Cunningham & Kettlewood, 1976; Morris & Holman, 1988) and of extent (does "loyal" refer to those customers who *only* buy from a single supplier or allow for those who divide their loyalty?) (Yim & Kannan, 1999), there is a philosophical distinction between those who perceive loyalty as an attitudinal antecedent of repeat purchasing and those who see loyalty as a behavioural outcome of repeat purchasing (Morris & Holman, 1988; Uncles & Laurent, 1997). From the purchasing and supply perspective, the question is one of strategic sourcing – to source from a single supplier or multiple suppliers (Owens Swift & Coe, 1994; Quayle, 2001)

In this context, Uncles et al (2003) identify three conceptualisations of loyalty:

(a) Attitudinal – loyalty driven by a disposition to continuing buying from the same supplier

(b) Behavioural – loyalty as observed in historic purchasing patterns

(c) Contingent – loyalty affected by disposition and the purchasing situation.

Jacoby (1971) defines loyalty as "the overt act of selective repeat purchasing based on evaluative psychological decision processes" and views repeat purchase behaviour as a necessary but not sufficient condition for loyalty. This implies that attitudes should be stable, enduring and deterministic. However, it has been shown that the attitudinal beliefs held by consumers towards suppliers (or brands, as much of the research in this area has been in consumer markets) can be rather volatile, perhaps because they are not very deeply held or because they are a consequence of average purchase behaviour (Dall'Olmo Riley et al, 1997). Rather than "the more they like it, the more they will buy it" (Baldinger & Rubinson, 1997) this would appear to be a case of "I use it, therefore I like it" (Ehrenberg, 1997).

Repeat purchasing may occur in the absence of any positive attitude towards a supplier where customers may be "trapped" by high switching costs or "purchased" through promotional pricing or reward programmes (Seth et al, 2005). It has also been noted that repeat purchase behaviour may be habitual, occurring in the absence of a psychological commitment to the vendor (Jarvis & Wilcox, 1977). Dick and Basu (1994) argue that loyalty combines both attitudinal and behavioural elements and identify four specific conditions as described in Figure 2.2 below.

		Repeat Patronage	
		High	*Low*
Relative Attitude	*High*	*Loyalty*	*Latent Loyalty*
	Low	*Spurious Loyalty*	*No Loyalty*

Figure 2.2 Loyalty conditions (Dick & Basu, 1994)

Loyalty is not a concept that features highly in the purchasing literature except to the extent that supply chain collaboration implies deepening relationships between buyers and a small number of suppliers (Patterson et al, 1999; Emberson & Storey, 2006; Vereecke & Muylle, 2006). Such relationships are often conceptualised as long-lasting (Hakansson & Wootz, 1979) but empirical evidence suggests that there may be high levels of turnover in the buyer's portfolio of relationships (Gadde & Mattsson, 1987; Dubois et al, 2003; Kamp, 2005). Portfolio models of purchasing encourage buyers to avoid becoming dependent on individual suppliers (Kraljic, 1983). The literature distinguishes between sole sourcing (where there is only one supplier to choose from), single sourcing (where a choice is made to only buy from one supplier), dual sourcing (two suppliers) and multiple sourcing. Single sourcing can deliver higher quality and lower total costs but may expose the buyer to a greater risk of supply chain disruption (Burke et al, 2007). Dual or multiple sourcing can spread risk but at the expense of higher coordination costs. A buyer may choose to satisfy most category requirements from a single supplier, just buying enough from the others to keep the relationship going (Costantino & Pellegrino, 2010). Although single sourcing is often presented as the result of a rational decision-making process, embedded costs, earned trust and idiosyncratic routines established through repeat interaction and buyer's organisational inertia can result in de facto single sourcing (Li et al, 2006).

It is often assumed that a high level of source loyalty is the norm in organisational markets (Jarvis & Wilcox, 1977; Hakansson & Wootz, 1979). This assumed loyal behaviour is the basis of the IMP approach (a long term

relationship implies loyalty) and in most conceptual models of buyer behaviour one of the attribute variables is previous experience or satisfaction with the supplier (Reichheld & Sasser, 1990). The assumed stability is perhaps one reason why there has been little empirical research into actual patterns of organisational purchase behaviour (Gadde & Mattsson, 1987). Such research often shows dynamic behaviour with a cyclical linkage between relationship strength and relationship performance (Autry & Golicic, 2010) but has not addressed what is purchased and from which suppliers.

In consumer research, panel data has been used to study the patterns of repeat purchase behaviour and model these patterns stochastically. Loyalty is measured in terms of actual purchase behaviour. Such studies have shown that the extent of brand loyalty can vary widely and that a high degree of loyalty is not necessarily a good thing as solely loyal customers tend to be less frequent purchasers than those with divided loyalties (Norman et al, 2005). Sharp et al. (2002) note the distinction between repertoire markets, where consumers satisfy their requirements from a repertoire of brands, and subscription markets where high levels of source loyalty are the norm. The few empirical studies carried out in organisational markets have shown similar patterns of repeat purchasing, mainly in fast moving industrial goods and services such as aviation fuel (Uncles & Ehrenberg, 1990), ready mixed cement (Pickford & Goodhardt, 2000) and financial exchange services (Bowman & Lele-Pingle, 1997).

Uncles & Ehrenberg (1990) analysed a selection of aviation fuel contracts held by airlines across different locations (airports). The analysis was static in that it only considered the contracts with a particular fuel supplier at a particular point

in time and did not take into account any repeat purchasing. Patterns of split loyalty, few 100% loyal buyers and no segmentation were observed. Similar patterns are observed in foreign exchange services (Bowman & Lele-Pingle, 1997) using survey data from corporations using financial services. The model over-predicts penetration with demand concentrated in a small number of heavy purchasers. Some non-stationarity is also observed such that when the Dirichlet model is parameterised using 1990 data it does not give accurate predictions for 1991 observed data. The ready mixed concrete study (Pickford & Goodhardt, 2000) uses survey methodologies to collect recall based purchase histories (previous three months) and Juster scale based purchase likelihoods (next three months). These purchasing records were then used to operationalise the Dirichlet model. The analysis demonstrated regular patterns of split loyalty with the only major deviation being an under-estimation of penetration (and over-estimation of purchase frequency) for the market leading supplier.

2.3.1 Purchasing Behaviour within the Buying Organisation

Much of the intra-organisational literature focuses on attitudinal and contingent loyalty (Bubb & van Rest, 1973; Jarvis & Wilcox, 1977; Dick & Basu, 1994). Wind (1970) identified the following four sets of variables to be determinants of source loyalty: product/service attributes (price, quality); buyer's past experience with suppliers; buyer's organisational constraints (policy, organisational objectives); factors that simplify the buyer's work.

The earliest examples of research into organisational purchasing behaviour built on existing consumer behaviour research to develop conceptual models of the organisational buying process (Robinson et al, 1967; Webster & Wind, 1972;

Sheth, 1973). While not explicitly focused on repeat purchasing or loyalty, these conceptual models addressed the phases of the buying process, the nature of the buying centre and the tasks carried out by the buying centre and the decision making processes used in organisational purchasing (Moller, 1985).

Robinson et al. (1967) proposed three categories of buying situation to describe heterogeneity in this aspect of organisational purchasing. Their "straight rebuy, modified rebuy and new task" classification addresses the issues of repeat purchasing in routine and non-routine contexts. It recognises the role played by uncertainty in purchasing decisions and how purchasing organisations respond to this uncertainty in terms of buyer search behaviour, information needs and decision processes. Sheth (1973) and Webster and Wind (1972) also note the importance of routine and the type of purchase as a moderator of purchasing decisions. The nature of the product has also been used as a basis for classification (Lehmann & O'Shaughnessy, 1974) with four categories identified: routine order products; procedural problem products; performance problem products; political problem products. The assumption is that product attributes will be valued differently by the organisational buyer depending on the categorisation of the product. Similar contingency models have been proposed in the purchasing and supply literature including portfolio models that categorise purchase situations and propose purchasing strategies based on dimensions such as the importance of purchasing and the complexity of the supply market (Kraljic, 1983) or the specific investments made by both buyer and supplier into a buyer-supplier relationship (Bensaou, 1999).

Uncertainty and risk reduction is identified by other authors as contributing to repeat purchasing and the establishment of long-term relationships (Sheth, 1973; Vyas & Woodside, 1984). Jarvis and Wilcox (1977) argue that most repeat purchase behaviour is determined by organisational constraints: the cost of evaluating new vendors, uncertainty reduction, perceived absence of choice and "automatic" repurchasing. From the purchasing perspective such constraints lead to purchasing interventions to reduce the number of suppliers employed and strengthen the relationships with the remaining suppliers (Hahn et al, 1986; Krause & Ellram, 1997; Ogden, 2006).

The integrated models of Webster & Wind (1972) and Sheth (1973) both conceptualise the organisational purchasing process in terms of exogenous (situational or environmental) factors and characteristics of the purchasing organisation, the decision making unit (buying centre) and the individuals that make up the buying centre. In each case the buyer's previous experiences with the supplier were noted as key factors influencing subsequent decisions. Other factors that have been identified as determinants of loyalty include satisfaction (Preis, 2003; Spiteri & Dion, 2004), involvement and brand equity (Bennett et al, 2005).

More recent research stresses the importance of long term relationships in organisational marketing (Doyle, 1995; Sheth, 2002). With the exception of the IMP Group of researchers (see next section), the marketing literature has generally regarded these relationships from the perspective of either supplier or buyer, with the relationship as "just a development within the marketing mix approach" (Mattsson, 1997). Satisfaction, service quality, relationship building and dissonance reduction are key elements of the loyalty literature (Barclay,

1992; Pine et al, 1995; Bennett et al, 2005). Relationship quality as measured by perceived service quality, commitment, trust and satisfaction has been proposed as a predictor of loyalty in organisational purchasing (Rauyruen & Miller, 2007). The purchasing and supply chain literature also emphasises the importance of long term collaborative relationships (Patterson et al, 1999; Emberson & Storey, 2006; Vereecke & Muylle, 2006).

Several studies have related future purchasing behaviour to past purchasing behaviour and suggest that the extent to which previous purchases influence future purchases may be due to constraints such as market structure (lack of suitable suppliers), adaptation to a specific supplier (switching costs), bounded rationality, technological heterogeneity, buying process centralisation or high personal involvement (Heide & Weiss, 1995; Soderlund et al, 2001; Yanamandram & White, 2006). High levels of buyer inertia have been observed (Hakansson & Wootz, 1979; Li et al, 2006) and it has been noted that relationships "may endure despite deterioration of service/product and/or despite monumental, even catastrophic, mistakes by suppliers" (Young & Denize, 1995). Attempts have been made to relate buyer behaviour to dimensions such as longevity and quality of relationship as measured by constructs such as buyer attentiveness, buyer dependence and flexibility (Bonner & Calantone, 2005).

These attitudinal and contingent models are often criticised for their lack of parsimony (Choffray & Lilien, 1978), difficulties in operationalising the concepts and variables involved (Campbell, 1985), the underlying assumption of rationality in professional purchasing (Smith & Taylor, 1985) and for their focus on description rather than explanation (Anderson & Chambers, 1985). Given

the complexity of the organisational buying process and the limits on freedom of action within the process, it is perhaps not surprising that attitudinal measures (preference or predisposition towards a particular supplier) have been shown to be less good predictors of future purchase behaviour than analysis of past behaviours (Soderlund et al, 2001).

2.3.2 Purchasing Behaviour between Organisations

The inter-organisational research tradition views loyalty as a product of buyer-seller interaction and focuses on the relationship as the unit of analysis (Morris & Holman, 1988). This strand of the literature focuses mainly on buyer-supplier vertical relationships and features in both the purchasing and supply chain literature (Vereecke & Muylle, 2006) and the marketing literature, in particular the work of the Industrial Marketing and Purchasing (IMP) group (Hakansson, 1982).

The IMP approach stemmed from a growing dissatisfaction with seller-dominated research that treated buyer and seller separately, focusing on ways in which an active seller could manipulate the marketing mix to stimulate a passive buyer to respond. A growing body of empirical evidence was showing that industrial marketing and purchasing was dominated by stable long term relationships between individually significant buyers and sellers (Hakansson & Wootz, 1979) and the intra-organisational tradition did not appear to be reflecting the way that industrial marketing and purchasing practitioners actually behaved. By focusing on new buying situations and discrete purchase decisions, often of capital equipment, routine purchasing behaviour was neglected (Campbell, 1985). The result of this dissatisfaction was a wide-ranging study to

explore and describe the nature of almost 900 buyer-seller relationships across five European countries (Cunningham, 1980), resulting in the interaction approach.

The interaction approach emphasises the buyer-seller dyadic relationship as the unit of analysis and differs from the intra-organisational research tradition in three main ways (Turnbull et al, 1996; Ford, 2004):

(a) buyers are heterogeneous and individually significant to their suppliers,

(b) buyers and sellers interact to develop an offering which may be complex and highly adapted,

(c) transactions are not isolated events but episodes embedded in a relationship where previous experiences and expectations have a significant impact.

The IMP tradition takes as its point of departure the behavioural model of loyalty where loyalty is defined in the historic purchasing record, or in this case the pattern of interactions that are present in a long-lasting relationship. The measure of loyalty is the characterisation of the relationship. The early inductive IMP research sought to describe "the pattern of dependencies between companies, the evolution of their dealings over time, the adaptations that each made to meet the requirements of the other party, and the inter-organizational person contact that took place" (Turnbull et al, 1996). The resulting interaction model (Cunningham, 1980) provides a framework for analysing relationships in terms of:

(a) The interaction process,

(b) The participants in the interaction process,

(c) The environment within which the interaction takes place,

(d) The atmosphere affecting and affected by the interaction.

Hakansson and Wootz (1979) rationalised the existence of long term buyer-supplier relationships to be a response to uncertainty of need, market or transaction. Other authors have noted the role of buyer uncertainty (especially in dynamic high technology markets); switching costs due to established relationships, adaptations in products or processes, incompatibility; situational factors including purchase importance; a perceived absence of choice; and the nature of the buying centre (Gadde & Mattsson, 1987; Hallen et al, 1991; Heide & Weiss, 1995) in determining the likelihood of staying with an existing vendor.

Stability or longevity are often suggested as indicators of commitment in long-term business relationships although empirical studies have questioned the notion of stability as a feature of business networks (Gadde & Mattsson, 1987; Kamp, 2005). It has also been noted that close relationships (and hence implied loyalty) may become burdensome through the costs of servicing the relationship, through high interdependency that prevents one party exiting the relationship or the opportunity costs foregone when one party to the relationship prevents another from developing other relationships. Such circumstances have been described as the "golden cage" becoming an "ugly prison" (Hakansson & Snehota, 1998).

The markets as networks approach has developed from the interaction model as the analysis moved beyond the buyer-seller dyadic relationship to consider the network of relationships within which a focal firm or individual relationship is located. The Actors – Activities – Resources (AAR) model is the primary

analytical framework encountered in the study of industrial networks (Hakansson & Johanson, 1992). Actors are those who interact within relationships, perform activities and control resources. Activities refer to the combination, development, exchange or creation of resources by actors. Resources are the means by which actors carry out network activities. The AAR model has also been extended to recognize that the mental models (schemas, network pictures) held by individuals and organisations have a key role in the understanding of behaviour in networks (Welch & Wilkinson, 2002; Henneberg et al, 2006).

A detailed discussion of the IMP research and the Interaction Model can be found in Hakansson (1982). The model has been criticised for its looseness (McLoughlin & Horan, 2002) and lack of consistency (Turnbull et al, 1996) with some confusion over the very definition of the term "relationship" (Mattsson, 1997). In their review of the literature of inter-organisational relationships, Cheung and Turnbull (1998) observe that the "findings are scattered" (p. 47) with research addressing the multi-dimensional, directional, structured, varied and evolutionary nature of relationships.

The model has also been criticised for being overly descriptive, for the implicit assumption that relationships are always good and should be strived for and for the focus on the dyadic relationship with little regard to the embeddedness of the relationship in the network context (Anderson et al, 1994; Hakansson & Snehota, 1998; McLoughlin & Horan, 2002). In addition, the approach has been criticised for its over-reliance on qualitative and interpretive research methodologies (Moller, 1994; Wensley, 1995). The theoretical concepts are not

well developed with recognised difficulties in the definitions of relationship, interaction and network position (Easton, 1995b).

Several authors have questioned the evidence for the persistence of long-term stable relationships (Easton, 1992) and indeed some have presented empirical evidence suggesting high levels of turnover in the portfolio of relationships held by a buying organisation (Gadde & Mattsson, 1987; Dubois et al, 2003; Kamp, 2005). While the IMP approach provides a rich description of change in a dynamic network of relationships, it lacks a quantitative dimension to describe and predict patterns of loyalty and defection in networks of relationships.

2.4 Quantitative Models of Organisational Behaviour

The research question seeks to understand the pattern of purchases in terms of what is bought, from which supplier, over a series of purchase decisions. The literature reviewed so far has mainly been concerned with explaining the constructs that develop around purchasing behaviour such as loyalty and its antecedents and persistent buyer-seller relationships rather than describing and explaining the actual patterns of purchases. For example, studies of customer "defections" report that 68 percent of customers leave *for no special reason* (Gee et al, 2008) and that 65 to 85 percent of *satisfied customers will defect* (Oliver, 1999). By quantifying and modelling patterns of behaviour, a foundation can be built for further explanatory theory. As Cunningham (1956) observes, *"… the why of brand loyalty behaviour can be effectively attacked by field interviewing only after we know its "what", "where" and "how much""*.

In contrast to the field of consumer marketing there has been relatively little quantitative modelling of organisational purchase behaviour in the form of econometric or stochastic models of supplier choice behaviour (Sheth, 1977; Brand & Leeflang, 1994). Moller (1985) notes the difficulty in developing generalisable models that apply across the heterogeneous business marketplace. In addition to heterogeneity, difficulties in modelling industrial markets also arise because there may be a small number of market participants, precluding meaningful cross-sectional analysis. Industrial marketing data are typically less available than consumer data and the complexity of organisational buying processes can make such models complicated, difficult to understand and operationalise (Brand & Leeflang, 1994; Brinkmann & Voeth, 2007).

Quantitative modelling applied to repeat purchasing can be categorised as econometric (aligned to the attitudinal dimension of loyalty), stochastic (aligned to the behavioural dimension of loyalty) or a combination of both. The econometric models attempt to a greater or lesser extent to explain or predict buyer behaviour using measured attributes, perceptions or intentions, to seek to answer the question "*why do which buyers purchase what they do, where they do, when they do, and how they do?*" (Hunt, 1983). The focus on determinism leads to the introduction of more variables, improved measurement and more explanations that are specific to a particular situation (Bass, 1974). In contrast, the stochastic modelling tradition in buyer behaviour research aims to describe how organisations actually buy before seeking to explain the observed behaviour. This approach is based on models that generalise across many different market situations. Stochastic modelling is also widely used in supply chain forecasting although these models are typically time dependent and

focused on inventory and material flow models rather than supplier choices (Beamon, 1998).

As Bass (1974) notes, perhaps not all behaviour can be understood completely. When it is impractical to include all relevant variables in an analysis or when variables may not be measured precisely, it is to be expected that no exact relation will hold between the measured variables. In such circumstances a stochastic relationship can be established by including a random variable described by a probability distribution (Arrow, 1968). In this perspective, repeat purchasing is assumed to arise at least partly independently of any attitudinal disposition or strong commitment towards the supplier (Uncles et al, 2003). In their editorial to the International Journal of Marketing Special Edition on Loyalty, Uncles and Laurent (1997) suggest that consumer loyalty to brands can be thought of as stochastic, not deterministic and can be conceptualised as a propensity to re-purchase.

The following discussion considers both econometric models and empirical generalisations in organisational and consumer repeat buying behaviour research.

2.4.1 Econometric Models

Multi-attribute choice models can range from simple weighted point models to more sophisticated logit regression models (Brand & Leeflang, 1994). Weighted point models have been used in organisational purchasing research to investigate the relation between satisfaction, involvement and attitudinal brand loyalty (Bennett et al, 2005), the relation between price, attitude, organisational variables and work simplification variables and source loyalty (Wind, 1970), the

relation between relationship strength and subcontractor performance, experience, size and job complexity (Autry & Golicic, 2010) and the impact of product, performance and relationship satisfaction on repurchase intentions (Preis, 2003). These models assume that buyers can be classified into homogeneous segments that respond in similar and predictable ways to a variety of attribute variables.

The multinomial logit regression model determines the probability that a buyer chooses to purchase from a particular supplier as a function of a selection of attributes of all the other alternatives. It combines stochastic probabilities with econometric decision variables, allowing the incorporation of marketing mix variables into the model (Guadagni & Little, 1983; Wagner & Taudes, 1986). There are few examples of the use of such models in organisational repeat purchase behaviour research. Heide and Weiss (1995) specified a logit model to describe the probability of inclusion in a buyer's consideration set of suppliers and the probability of switching supplier in high technology markets.

Li et al (2006) use a discrete choice analysis (DCA) approach to demonstrate the prevalence of switching inertia in the U.S. industrial-automation industry. An experimental alternative supplier was presented to respondents who were asked to choose between the attributes of the experimental supplier and their incumbent supplier. Supplier selection multinomial logit models were estimated from the DCA to determine the effect of the attribute on supplier choice. This is used to determine the relative weight (importance) for the attributes and to estimate the switching inertia i.e. the likelihood of switching to the experimentally generated supplier.

Gensch (1987) uses a maximum-likelihood-hierarch (MLH) model and a logit model to predict organisational purchasing behaviour in a two stage disaggregate model. The first stage is a screening process to short list the available alternatives, modelled by MLH. The second stage is the supplier choice process modelled by logit. Predictions are made at the individual level, i.e. that individual *i* will select a particular alternative. These individual predictions can then be averaged to give an aggregate probability for the chosen alternative. Gensch (1987) reports prediction accuracy of 65% (i.e. the model accurately predicted the stated intention of 65% of the sample) compared to 30% for a simple weighted model. Some of this increase is attributed to the two-stage nature of the model, in that compared to the single stage model the two-stage variant has twice the parameters and two passes at the data. The analysis looked only at purchase intention and did not attempt to examine actual purchasing behaviour.

While these models are often evaluated in terms of goodness of fit and predictive accuracy, the behavioural logic underpinning the model and the normative managerial implications should not be overlooked (Gensch, 1987). In his analysis, Gensch (1987) identified two dominant attributes in the screening phase; manufacturing quality and problem solving. The dominant attributes may change between the phases. However he identifies the limited generalisability of this method by noting that "*one can only say that the two-stage model better approximates the actual choices of the individuals in this particular data set*" (p. 234).

In their review of the state of the art in global purchasing research, Quintens et al (2006) question the added value of advanced theory-testing structural equation models and note that the purchasing field requires more profound and longitudinal case-based studies that allow a more in-depth exploration of the phenomenon under study.

2.4.2 Empirical Generalisations

The best-fit single set of data approach for testing advanced theories is contrasted with a modelling approach based on empirical generalisations that are validated by replication on multiple sets of data. Regularities in both purchase incidence and brand choice have been observed and documented in consumer and, less frequently, in organisational buyer behaviour research (Ehrenberg, 1959; Easton, 1980; Uncles & Ehrenberg, 1990; Stern & Ehrenberg, 1995). These regularities have been shown to occur over a wide range of purchase situations, product classes and time periods, to the extent that they become empirically generalisable, that is they become "a pattern or regularity that repeats over different circumstances and that can be described simply by mathematical, graphic or symbolic methods" (Bass, 1995).

Empirical regularities or patterns prompt the establishment of empirically grounded theory. The theory is tested more widely under different conditions to extend its generalisability and develop it conceptually. Ehrenberg (1994) has dubbed this approach "Empirical then Theoretical" (EtT) in contrast with "Theoretical in Isolation" (TiI), the more traditional hypothetico-deductive econometric approach where a theory is proposed and then tested empirically.

The Empirical then Theoretical (EtT) approach is described in typically parsimonious fashion by Ehrenberg himself (Ehrenberg, 1994).

(1) Establish a generalisable empirical pattern

(2) Develop a (low-level) theoretical model or explanation

Bass and Wind (1995) present a selection of empirical generalisations ranging from the Bass diffusion model describing adoption of new technologies in terms of the number of previous adopters (Bass, 1969) to the NBD-Dirichlet model describing repeat buying behaviour in a stationary, non-partitioned market (Goodhardt et al, 1984).

2.4.2.1 Negative Binomial Distribution

One of the longest established empirical generalisations describing buyer behaviour is the Negative Binomial Distribution (NBD) model for purchase incidence and repeat buying behaviour (Ehrenberg, 1994). The operationalisation of the model is described in more detail in Chapter 3. The NBD is based on two assumptions relating to purchase incidence (Ehrenberg, 1959):

(a) An individual's successive purchases of the product category are distributed as-if-randomly over time with a constant long term mean purchasing rate for a specific time period. A zero-order process is assumed, i.e. the timing of successive purchases is independent of when the previous purchase was made. The number of purchases made in successive time periods then follows a Poisson distribution.

(b) Customer heterogeneity in the long run mean purchasing rates are assumed to be distributed through the population of buyers according to a Gamma distribution.

The gamma assumption of the NBD model has been theoretically justified using probability theory (Chatfield & Goodhardt, 1975), and based on two empirically supported assumptions that the long run mean purchasing rates are independent between individuals (i.e. one individual's purchasing rate does not affect another) and that the proportion of purchases devoted to a particular supplier is independent of the total rate of buying.

The Poisson distribution is justified under the assumption that the specific time periods are not too short, such that the zero-order assumption holds. A number of extensions of this model have questioned the Poisson assumption and these will be discussed below.

2.4.2.1.1 Zero-order Assumption

The assumption that the timing of subsequent purchases is independent of the timing of previous purchases (the zero order assumption) has been questioned (Jeuland et al, 1980; Dunn et al, 1983). They argue that just after a purchase is made, the probability of rebuying is small, and less than the long run purchasing rate of the Poisson. A second order Erlang distribution is proposed as an alternative to the Poisson. This has been named the Condensed Negative Binomial Distribution (CNBD) as it implies that individual purchasing behaviour is more regular (condensed) than the exponential form of the Poisson distribution (Chatfield & Goodhardt, 1973). For heavily purchased products, the beta binomial distribution (also known as Polya or negative hypergeometric

distribution) has been proposed to model the probability that a consumer makes a purchase in any one week (Chatfield & Goodhardt, 1970).

Morrison and Schmittlein (1988) also raise concerns about the zero order ("memoryless") assumptions of the Poisson. They argue that changing the distribution of inter-purchase times of the NBD from Poisson (Erlang-1) to Erlang 2 is a "good first step toward "improving" the NBD". Neverthless, the "plain vanilla" NBD model has worked well in numerous situations and has been shown to be an accurate predictor of future purchasing patterns (Morrison & Schmittlein, 1988). Chatfield and Goodhardt (1973) conclude that changing from Poisson to Erlang does not lead to any great improvements in the accuracy of the model and that the Poisson assumption should be favoured because it is simpler to use. They argue that for individuals with low average purchasing rates, the Poisson and Erlang 2 distributions are very similar. With low weekly purchase probabilities, the probability of buying in successive weeks is near zero and it is not necessary to make any special assumptions to treat behaviours immediately after making a purchase (Ehrenberg et al, 2004). For most consumer goods, these light-buying individuals form the majority of consumers (Chatfield & Goodhardt, 1973).

2.4.2.1.2 Extensions to the NBD

Several authors have proposed extensions to the basic NBD model of purchase incidence. These extensions variously incorporate brand choice (Bass et al, 1976; Goodhardt et al, 1984), segmentation and econometric variables (Bass & Pilon, 1980; Dillon & Gupta, 1996; Stern & Hammond, 2004) and modelling of

"inactive" customers in customer base analysis (Schmittlein et al, 1987; Peter et al, 2005; Fader et al, 2005).

2.4.2.1.2.1 Customer Base Analysis

Customer Base Analysis builds on the NBD by including the probability that a customer is still active as well as the purchasing frequency of active customers. In circumstances where customers may become inactive without the supplier organisation being notified, customer base analysis provides a way of modelling active customers and predicting future purchase behaviour (Schmittlein et al, 1987). The Pareto-NBD model proposed by Schmittlein et al (1987) is based on the NBD (Poisson purchase rates distributed according to a gamma distribution across the population) with two additional assumptions relating to "death" rates, i.e. the probability that a customer becomes inactive after a particular time period. It is assumed that the lifetime of each customer follows an exponential distribution and that these lifetimes are distributed across the population of customers according to a gamma distribution. The final assumption of the Pareto-NBD is that the purchase rates and death rates are independent.

The parameters of the Pareto-NBD model are determined from historical purchasing data. As sales and order data are usually readily available within the supplier's information systems, this model can be used in circumstances where panel data is not collected or where data collection is expected to be problematic. The model can then be used to predict the number of current customers that are expected to still be active at some future time. The future purchasing activity of these customers can also be predicted to determine a Customer Lifetime Value (CLV). Schmittlein et al (1987) acknowledge that

more work is needed to develop effective methods for estimating the four parameters of the Pareto-NBD. Perhaps as a consequence of this, there are very few reported empirical applications of the model (Fader et al, 2005). Fader et al (2005) identify one application using maximum likelihood parameter estimation and one using a three-step method of moments estimation procedure. They propose a new model, the Beta-Geometric-NBD (BG-NBD) that is easier to implement.

The Pareto model assumes that a customer can become inactive at any time. In contrast, the Beta-Geometric model assumes that "death" occurs immediately after a purchase (Fader et al, 2005). The probability that a customer becomes inactive immediately after the purchase is distributed across the transactions according to a geometric function and across the population of customers according to a beta distribution. The four parameters of the distribution can be estimated using a maximum likelihood procedure. Fader et al (2005) test the BG-NBD model and the Pareto-NBD model on retail data in what they claim is only the second empirical validation of the Pareto-NBD model. The first reported empirical validation was carried out using order date and dollar volume per order for an office products suppliers serving business customers (Schmittlein & Peterson, 1994). A further validation has been carried out on grocery retail data, using the Pareto-NBD, the BG-NBD and a Modified BG-NBD (MBG-NBD) to allow for customers that become inactive immediately (Batislam et al, 2007). Although the Pareto-NBD model may be suited to industrial applications where scanner data is not available but sales records do exist (Easton, 1980), it provides no information about supplier choice and has had very limited empirical application.

2.4.2.1.2.2 Econometric Variables

It is a frequent criticism of stochastic models that they do not explicitly contain any marketing variables and thus are said to provide no information about underlying causal mechanisms (Bemmaor, 1994; Popkowski Leszczyc & Bass, 1998) and have few findings of managerial significance (Wagner & Taudes, 1986). Similarly, econometric models that only include decision variables have often been criticised for ignoring the underlying heterogeneity in the customer population (Bass & Pilon, 1980). Popkowski Leszczyc and Bass (1998) present an analysis of the treatment of heterogeneity in marketing models, highlighting the distinction between heterogeneity included *outside* the likelihood function (i.e. additional to the distribution of purchase probabilities) and heterogeneity included *within* the likelihood function (either by including a dummy variable for each member of the population or by assuming a mixing distribution for the parameters).

Several models combine logit models to explain brand choice probability in connection with the NBD model of purchase incidence (Jones & Zufryden, 1980; Wagner & Taudes, 1986). An alternative approach to modelling heterogeneity is to adopt a latent class approach by partitioning the population into homogeneous segments that are defined by the customer's response to marketing variables (Dillon & Gupta, 1996). While many such models claim an improvement in goodness of fit, this is perhaps unsurprising as the models are parameterised to fit the data, using maximum likelihood estimators. What would be more surprising would be if the models were to fit well to a new set of data. The improved fit usually comes at the expense of parsimony. For example, Dillon and Gupta (1996) compare their latent class model (151

parameters, percentage error 1.5%) to the NBD-Dirichlet (9 parameters, percentage error 2.4%). It is debatable whether the extra 0.9 percentage point accuracy justifies the additional 142 parameters.

All the empirical testing of these models has been carried out in a fast moving consumer good environment where data on purchase rate, product choice and marketing variables (including demographics, price, promotional activity) are available. The lack of industrial applications of the models may be linked to the lack of data relating to explanatory variables including knowledge of competitor offerings and customer purchases of other firm's products. This lack of data "rules out the logit-type analyses of customer product choice" (Schmittlein & Peterson, 1994).

In addition, the incorporation of econometric variables into stochastic models introduces the limitations associated with the single set of data approach. The models are relevant to a particular data set and do not exhibit the generalisability that characterises stochastic models like the NBD that so many of the combined models are based upon. Morrison and Schmittlein (1988) note that it makes more sense to use established stochastic models to set a baseline from which to assess the effect of marketing mix variables. Econometric techniques can then be used to explain discrepancies from the baseline. It has also been noted that steady state models can provide a useful comparison for more complex dynamic models (Jeuland et al, 1980). This approach will be seen later in explanations of deviations from Dirichlet norms (Fader & Schmittlein, 1993; Bhattacharya, 1997; Stern & Hammond, 2004).

2.4.2.1.2.3 Supplier (Brand) Choice

Other researchers have extended the NBD model of purchase incidence to include brand choice by incorporating a multinomial probability law for the shares of a particular brand. A multi-variate beta distribution is often assumed to describe the distribution of choice probabilities (Chatfield & Goodhardt, 1975; Bass et al, 1976).

Bass et al (1976) start from an assumption that individual utilities for each consumer for each brand are distributed over the population according to a gamma distribution. They show that for a given purchase occasion, the brand choice probabilities resulting from this distribution of utilities are distributed as beta. By considering a series of purchase occasions they derive a compound beta-binomial (Polya-Eggenberger) distribution that describes brand switching, penetration and duplication. The model parameters are the market shares of the brands and the "product class loyalty factor", a measure of the correlation between successive purchases of a brand. As the number of purchase occasions becomes very large, the limit of the Polya-Eggenberger distribution is shown to be the NBD.

Chatfield and Goodhardt (1975) use probability theory to mix the binomial distribution of purchase frequencies for each brand with a beta distribution to give a beta-binomial distribution. This distribution is used to predict the probability that a particular brand is purchased *r* times, given *n* purchases of the product category. This follows from the assumption that the distribution of purchases for each brand follows the NBD, and that the NBD for each brand is independent of the NBD for other brands. In addition, the brand choice

probabilities are assumed to be independent of purchase rate. This independence means that the individual NBDs can be combined to create a joint distribution of purchase frequencies of brands in the product category, and hence the model of multibrand buying behaviour. Chatfield and Goodhardt (1975) indicate the limitations of some of the simplifying assumptions made in their model and propose the use of a multivariate beta distribution of brand choice (the Dirichlet distribution) rather than the multivariate NBD.

The assumption of the Dirichlet distribution for brand choice was developed by Shoemaker et al. (1977) who proposed the Frequency Dependent Dirichlet (FDD) to model the dependence of purchase probabilities on purchase frequencies. They found that some brands exhibited independence between choice probabilities and purchase frequencies and others (often major brands) exhibited dependence. However they concluded that the independence assumption was a "good first approximation". Jeuland et al. (1980) also adopted the Dirichlet distribution in their integrated brand choice and purchase timing model, using an Erlang-2 model of purchase timing. They provide expressions for typical market statistics including repeat buying, brand switching, penetration and duplication. The empirical application of the model on consumer panel data showed some discrepancies between the expected and observed results for repeat buying. Jeuland et al. (1980) concluded that the assumption of a zero-order model did not hold and proposed that some dependence on previous purchases be incorporated into the choice model. Chatfield and Goodhardt's (1975) model was also developed into the NBD-Dirichlet model of buyer behaviour (Goodhardt et al, 1984). This model will be described in more detail below.

2.4.2.2 NBD-Dirichlet Model

Of all the models combining purchase incidence and brand choice, the NBD-Dirichlet is perhaps the best known and certainly the most extensively validated. Since its development, it has been applied in studies across over fifty varied product or service categories including fast moving consumer goods, store choice, medical prescriptions and television choice (Uncles et al 1995) and for product variants within fast moving consumer good brands (Singh et al, 2008). Although there has been limited research into the application of the model to organisational purchase situations, the few studies that have been carried out represent more research than has been done for all of the other models discussed.

The NBD-Dirichlet rests on five assumptions relating to purchase rates and brand choice (Goodhardt et al, 1984; Dacko, 2008). The first two assumptions are those of the NBD:

(a) Individual purchases distributed Poisson

Successive purchases by each individual are spread over time "as if random", independent of each other (zero order) with a constant mean rate in a specified unit length time period.

(b) Gamma distribution for individuals' different mean purchase rates

The validity of the NBD assumptions has been discussed above and will not be repeated here. In the model the NBD is used to model the number of purchases of the whole product category made by all individuals in the time period chosen as the unit of analysis (Goodhardt et al, 1984; Ehrenberg et al, 2004).

The next two assumptions concern brand choice:

(c) Zero order multinomial distribution for brand choice on a specific purchase occasion

Brand choices made by an individual over a series of purchases are spread randomly with a fixed probability of choosing a particular brand. These probabilities are independent of previous purchase choices (zero order).

(d) Brand choice probabilities distributed according to a multivariate Beta distribution (Dirichlet)

These assumptions will only be valid for conditions of stationary markets (i.e. fixed purchase probabilities) and no market partitioning (Goodhardt et al, 1984; Sharp & Driesener, 2000). Challenges to these assumptions will be addressed in the next section.

The fifth assumption considers the relationship between brand choice and purchase incidence:

(e) The brand choice probabilities are distributed over the population independently of the average purchase frequencies of individual purchasers.

The assumptions of stationary and non-partitioned markets and of the independence of brand choice and purchase incidence have been challenged often (Shoemaker et al, 1977; Fader & Schmittlein, 1993; Bhattacharya, 1997; Sharp & Driesener, 2000; Stern & Hammond, 2004). Much marketing research is focused explicitly on dynamic and partitioned markets with the emphasis on manipulation of marketing mix variables to influence the behaviour of particular, distinct market segments and hence to assume stationary and

unsegmented markets may seem unrealistic and uninteresting (Ehrenberg et al, 2004).

For frequently purchased, low involvement products the zero order and stationary market assumptions have generally been accepted as good approximations. In such circumstances customers are generally highly experienced and their long run brand preferences are not easily influenced by further purchases or promotional activity. Typically the brand choice decision is made quickly with little information processing. This behaviour has been described as habitual and routinised (Popkowski Leszczyc & Bass, 1998; Ehrenberg et al, 2004). Short term responses to promotions are observed but the main impact appears to be to bring forward purchases by existing purchasers of the brand. After the promotion brand preferences typically return to the long run average propensities (Ehrenberg et al, 1994).

The extension of these assumptions to high involvement purchases would appear to be less intuitive as infrequent purchasing is unlikely to lead to habit-forming behaviour and high involvement implies a more complex decision making process. However it has been noted that infrequent purchasers may have more opportunity to "forget", hence the zero order assumption may be justified (Stern & Hammond, 2004). In addition the empirical evidence shows that the Dirichlet model holds over a wide variety of purchasing situations including consumer durables and cars (Ehrenberg et al, 2004). Repertoire markets, where consumers purchase from a repertoire of familiar brands, might be expected to be characterised by routine behaviours but it has been shown that the Dirichlet also holds for subscription markets where sole loyalty is the norm (Sharp et al, 2002).

It has been suggested that the model is so general that it will hold in all circumstances. Sharp and Driesener (2000) show that systematic violations to the Dirichlet assumptions, in particular the non-partitioned assumption, do result in a poor fit for the model.

The assumption of unsegmented markets means that brands competing in the same market space are mostly alike and directly substitutable. Where segments do exist, they are generally the result of functional differences, for example ground coffee or instant, caffeinated or decaffeinated (Ehrenberg & Sharp, 2000). In the case of Sharp and Driesener's (2000) study of café choice, they noted functional partitioning in terms of restaurant type (pizza, sandwich, organic vegetarian) and a niche segment that had a few highly loyal purchasers. The Dirichlet model holds for directly substitutable brands and it can be used to identify clusters by examining duplication of purchases i.e. the proportion of purchasers of one brand who also purchase another brand. The "Duplication of Purchase Law" is an approximation that states that the proportion of buyers of one brand who also buy a second brand in the analysis period is proportional to the penetration of the second brand (Ehrenberg, 1988). The duplication coefficients will be different for each distinct segment (Ehrenberg & Sharp, 2000).

The final assumption that brand choice is independent of purchase incidence has also been challenged by identifying segments based on purchase frequency (Shoemaker et al, 1977; Fader & Schmittlein, 1993; Stern & Hammond, 2004). Shoemaker et al. (1977) conclude that the independence assumption is a good first approximation although they note a strong dependence between purchase

probability and purchase frequency for several major brands. This finding was also noted by Fader and Schmittlein (1993) who examined the "repeat purchasing premium" enjoyed by large (i.e. high market share) brands. They compare the deviations between actual Share of Category Requirements (SCR) and observed SCR to identify any relation with market share. They observe a correlation ($r = .317$, $p < 0.10$) between purchase frequency and the repeat purchase premium. Excess repeat purchasing is also connected to the existence of segments that may be highly loyal to the high share brands or the existence of distinct sub-markets (functional segments). Stern and Hammond (2004) analyse purchase incidence heterogeneity as an explanation for the "repeat purchasing premium". By comparing loyalty across an equal number of purchases (rather than an equal time period) they observe clear differences between groups of buyers segmented by rate of category purchase with consistently lower loyalty exhibited by lighter buyers. Calculated loyalty measures are dependent on the number of purchases used to operationalise the model such that over short purchase runs (up to about 15 purchases) loyalty is underpredicted. At low purchase rates the Dirichlet predictions are closer to the actual values for light buyers than for heavier buyers. As heavier buyers make a larger contribution to the sales of a particular supplier, this effect can lead to the observed market share or repeat purchasing premium noted above.

2.4.2.2.1 Implications and Uses of the NBD-Dirichlet

The Dirichlet model describes and predicts patterns of purchasing behaviour that have been observed in many different markets. These include the following (Goodhardt et al, 1984; Ehrenberg & Sharp, 2000; Ehrenberg et al, 2004):

(i) The average rate of purchase of the brand is approximately constant across all the brands with a slight decrease from larger to smaller brands (the "Double Jeopardy" effect)

(ii) Market shares and penetrations decrease greatly from high share to low share brands

(iii) Buyers of a particular brand tend to buy other brands quite often

The significant implication for marketing managers is that an increase in sales must be delivered by an increase in the number of customers. If average rates of purchasing are roughly constant across all brands then it seems futile to expect sales growth to come from getting existing customers to buy more (Goodhardt et al, 1984). In unsegmented markets a kind of competitive equilibrium prevails where competition means "running hard to stand still" to ensure that the brand remains in the repertoire of split-loyalty customers (Ehrenberg et al, 2004; Singh et al, 2009). The Dirichlet incorporates marketing mix variables by assuming that they are subsumed into the brand's market share (or penetration). Loyalty measures (for example SCR) are dependent on consumer preferences, positioning, marketing mix and competitive activity, all factors that will also determine market share (Bhattacharya, 1997). The dominance of market share as the determining variable for brand performance reflects the observation of Jarvis and Wilcox (1977) that "much of what appears to be true vendor loyalty is chance loyalty" (p. 10).

The "Double Jeopardy" effect means that smaller brands not only have fewer buyers but those buyers also purchase less often. This effect was noted (and named) by McPhee (1963) who observed that the more popular radio DJs and

comic books had more listeners (readers) and those listeners listened for longer each day. In a market with two brands, one large and one small, the small brand will have a few users most of whom will know of and may use the larger brand. By contrast the large brand will have a lot of users, many of whom may not be aware of and have never used the smaller brand. This is the statistical selection effect that leads to Double Jeopardy (Dall'Olmo Riley et al, 1997). The Dirichlet predicts the Double Jeopardy effect quite accurately although the under-prediction of brand loyalty for high share brands has been discussed above (Fader & Schmittlein, 1993).

McPhee (1963) also notes the phenomenon of Natural Monopoly whereby the most popular products "monopolise" light buyers of the category while heavy buyers tend to choose a mix of larger and smaller brands. Even those buyers who choose the smaller brands regularly will tend to satisfy most of their requirements with larger brands and will tend to appreciate the larger brands more than the less popular alternatives (Elberse, 2007). This leads to Double Jeopardy as smaller brands are chosen by experienced purchasers who are knowledgeable with the competing alternatives while light purchasers are less aware of the choices available. Double Jeopardy arises from the lack of awareness of competing brands combined with a tendency for smaller brands to be bought mainly by consumers who have the highest standards (McPhee, 1963). In a study of DVD rentals Elberse (2007) confirms that consumers of "obscure" products (equivalent to smaller brands) are more likely to be heavy consumers of the category. She observes that heavy consumers or those with more knowledge of a category may face fewer obstacles in identifying alternative brands.

As a well-established empirical generalisation that has been validated over many different markets, the Dirichlet can be used as a benchmark or baseline for researchers (Fader & Schmittlein, 1993; Bhattacharya, 1997; Uncles & Laurent, 1997) so that deviations can be identified and researched more fully. The Dirichlet norms can also be used to assess the performance of existing brands (Ehrenberg & Sharp, 2000; Ehrenberg et al, 2004) to identify and explain any discrepancies or to analyse dynamic market situations, for example short term promotional response. An often quoted example concerns the prescription of a cardio-vascular drug, Capoten. 10 new prescriptions a year were being written for Capoten compared to the norm of about 5. It was noted that doctors were being provided with a free personal computer if they prescribed Capoten often enough for monitoring purposes. The prescribing rate returned to normal after the promotion ended (Stern & Ehrenberg, 1995).

Extending the Dirichlet norms to new markets also provides a basis for analysis. The first step is to establish whether the new conditions follow the Dirichlet norms, and to identify and explain any discrepancies. For example, as has already been noted, the Dirichlet can be used to identify clusters by examining duplication of purchases i.e. the proportion of purchasers of one brand who also purchase another brand. The introduction of a new brand into an established Dirichlet market can also be modelled to estimate repeat purchase rates for the new brand (Ehrenberg & Sharp, 2000).

2.4.3 Model Selection

Barwise (1995) presents five characteristics of a good empirical generalisation:

(a) Scope. A good empirical generalisation is known to hold over a wide range of different conditions

(b) Precision. A good empirical generalisation describes the observed phenomena accurately

(c) Parsimony.

(d) Usefulness. A good empirical generalisation is one that practitioners find useful.

(e) Link with theory.

On all five characteristics the Dirichlet scores well over any of the other models assessed in this literature survey. It has been validated in over fifty discrete marketing situations, including several in an organisational setting. It describes the observed patterns of purchasing, including Double Jeopardy, accurately. It does this with a relatively small number of parameters ($n+2$, where n is the number of brands under study). The input parameters are the penetration and average purchase frequency for the product category and for one or more of the brands in the category.

The model has found wide application as a baseline for assessing market dynamics and brand performance (Ehrenberg et al, 2004). Finally, it is well supported by the theory of stochastic preference. The assumptions underpinning the model have been challenged extensively, yet they continue to be used as "good first approximations" (Shoemaker et al, 1977). As Uncles et al. (1995) note "the Dirichlet model may be the best-known example of an empirical generalisation in marketing".

2.4.3.1 Extension of B2C to B2B

Although the Dirichlet has been extended to industrial purchasing cases in a few examples, most of the work has been carried out in consumer markets. It is reasonable to question to what extent the B2C findings are compatible with a B2B context and to what extent a replication study in B2B can be considered a differentiated replication of a model of consumer buying behaviour.

Several authors have argued that the distinctions between B2C and B2C are becoming blurred or are unjustified (Fern & Brown, 1984; Wilson, 2000; Wind, 2006). Consumer purchases may involve several influencers in a protracted decision process (for example family decisions), may be subject to derived demand (for example gift purchases), may involve knowledgeable and experienced purchasers and are moderated by cultural and societal norms (Fern & Brown, 1984).

However, while there may be some observed blurring of the boundary for particular buying situations or buyers, most marketing textbooks continue to draw a distinction between B2C and B2B. For example, (Kotler, 1991) has a chapter focused on "the industrial market" that identifies several characteristics setting organisational markets apart from consumer markets. These include a smaller number of larger buyers, the existence of closer supplier-customer relationships, geographically concentrated buyers, derived demand (i.e. industrial purchasers buy to satisfy the demand of their own customers), inelastic demand, fluctuating demand (especially for capital equipment purchases) and professional purchasing organisations with more influencers involved in the buying process.

"Organisational buying is an example of multi-phased, multi-person, multi-departmental, and multi-objective processes. It is composed of individual, departmental and company-level interactions."

(Moller, 1985)

Notwithstanding these characteristics, many organisational purchases are frequently purchased straight rebuys, routine and proceduralised (Robinson et al, 1967; Wilson, 2000). Purchasing of these "fast moving industrial goods" is similar to the purchasing of fast moving consumer goods (Easton, 1980) and indeed the previous applications of the Dirichlet to B2B, in aviation fuel, foreign exchange services and ready mixed concrete, are examples of such routine purchases.

The long term buyer-supplier relationships that form the basis of the IMP view of B2B may seem to conflict with the "as if random" purchasing behaviour that underpins stochastic modelling. This may be true when companies have exclusive relationships but for many frequently purchased goods, companies will maintain relationships with two or more suppliers (Kraljic, 1983). In such circumstances, particularly when the purchases are routinised and purchasing behaviour becomes habitual, buyer behaviour can be described in terms of split loyalty purchasing within a repertoire of supplier relationships in an "as if random" manner.

The extension of the NBD-Dirichlet to organisational purchasing, particularly for frequently or routinely purchased categories, is a logical and proven extension of a B2C model into a B2B context. Although there may be similarities between purchasing of fast moving industrial goods

and fast moving consumer goods, the specific differences between organisational and consumer markets set out above remain. These differences: fewer and larger buyers; derived demand; professional purchasers, mean that the extension of the NBD-Dirichlet to B2B can be considered a differentiated replication and an attempt to identify a proposition that is generalisable across industrial and consumer marketing (Fern & Brown, 1984).

2.4.3.2 Complementarity with other research traditions

The previous discussion has shown the limitations of the intra-organisational tradition in explaining and predicting buyer behaviour in terms of attitudinal and supplier-controlled (marketing mix) variables. The models derived are difficult to operationalise and lack generalisability and predictive power. The inter-organisational tradition provides a richer view of the reality of much organisational purchasing by acknowledging and focusing on network relationships. However, the approach lacks a quantitative dimension to describe and predict patterns of loyalty and defection in networks of relationships.

The NBD-Dirichlet model has been identified as a well established, robust and parsimonious model to describe and predict organisational repeat purchasing behaviour. The Dirichlet norms provide a baseline against which deviations can be investigated using either the econometric or the relationship-based techniques described previously. In this way the stochastic modelling approach using the Dirichlet is complementary to the other research traditions. This builds on the work of Gadde and Mattsson (1987) who propose longitudinal analyses similar to the repeat buying analyses carried out on consumer panel data in order to

describe stability and change in network relationships – "to study the proportion of newly established, continuing and disrupted relationships". Despite calls for an integrative approach and greater direction to the study of industrial buying behaviour (Anderson & Chambers, 1985; Johnston & Spekman, 1982; Moller, 1985), research into organisational purchasing behaviour remains highly fragmented.

The value of steady state models as a baseline for comparison for dynamic market conditions is widely recognised (Jeuland et al, 1980). These comparisons are important when the baseline norms are known to be reliable and when deviations are systematic (Bhattacharya, 1997). Other techniques can then be used to explain the discrepancies outside the Dirichlet rather than making a widely generalisable and parsimonious model more complex (Morrison & Schmittlein, 1988; Bhattacharya, 1997). As Jeuland et al. (1980) note "there are too many instances in which more complex models do not outperform simpler ones".

2.5 Summary

The review of the extant collaborative procurement literature has revealed a lack of research that describes the actual purchasing behaviour of organisations that are members of purchasing groups. When so much of the savings potential that can be derived from group purchasing relies on changing purchasing behaviours, in particular influencing members to change their distribution of purchases between particular suppliers, this lack of understanding of how member organisations actually purchase is a significant gap in the literature.

Changing purchasing behaviour will require overcoming the loyalty that particular purchasers will exhibit towards particular suppliers. The literature review has examined different concepts of loyalty, including long term buyer-supplier relationships and quantitative modelling approaches that seek to explain buyer loyalty (or inertia) in terms of product, supplier, buyer, environmental or relationship attributes. However when considering how buying behaviours in collaborative procurement organisations will change as a result of collaborative purchasing efforts, it is clear that loyalty will be dynamic and that changes in behavioural loyalty (i.e. what is actually bought) may be mandated and therefore may not reflect underlying attitudinal preferences. Attitudinal loyalty may catch up with the behaviours after the buyers have gained familiarity with the supplier. It is important to consider what is actually bought when considering changes in purchasing, and in particular repurchasing behaviour.

This focus on describing and modelling actual purchase behaviour leads to the selection of the NBD-Dirichlet empirical generalisation as the model to be used in the research. It has been replicated in over fifty distinct purchasing situations and provides accurate predictions of buyer behaviour with a small set of inputs, readily available to purchasing managers. This study will involve an extension into a complex collaborative public procurement environment, a substantial contribution to the Dirichlet literature. In addition, the Dirichlet is used by consumer marketers to benchmark brand performance; applying the model in a purchasing context is a novel approach and a major contribution to the theory and practice of purchasing and supply chain management.

The following chapter sets out the epistemological assumptions underpinning the research and the research methodology to be followed, including the data collection and analysis, the parameterisation of the NBD-Dirichlet model and the interpretation of the results.

3 Research Methodology

3.1 Introduction

The previous chapter has highlighted the importance of describing the "what", "when" and "how much" of organisational purchasing behaviour before attempting the "why" (Cunningham, 1956). This approach has informed research into the macro-structures of collaborative purchasing organisations but there has been no accompanying research into the behaviours of the collaborating organisations – how the members of the group actually buy and how these patterns are transformed by being part of the purchasing group.

This focus on describing and modelling actual purchase behaviour leads to the selection of the NBD-Dirichlet empirical generalisation as the model to be used in the research. The previous chapter has discussed why this model is a good choice for the study of behaviours in purchasing consortia; this chapter presents the epistemological assumptions that underpin the research, in particular the role played by replication within the Empirical then Theoretical (EtT) approach advocated by Ehrenberg (1994). The research is located within the Lakatosian concept of sophisticated methodological falsification within a research programme (Leong, 1985).

The research methodology is also presented, including data collection, operationalisation of the model and testing the model. Data is collected from a Collaborative Procurement Hub (CPH) within the English National Health Service (NHS). As has been noted, the extension of the model into a collaborative public procurement environment is a differentiated replication, an

extension into a very different set of conditions from those usually encountered in Dirichlet applications (Lindsay & Ehrenberg, 1993). This replication extends the generalisability of the model and its practical applicability, in this case into a new discipline as well as a new market. The longitudinal nature of the study, covering a period during which the market undergoes dynamic change, means that the suitability of the model to describe and predict market changes as well as to monitor the impact of collaborative purchasing interventions is also investigated. Worked examples using data from a pilot study are used to demonstrate the calculation methods.

3.2 Empirical then Theoretical

The research is a differentiated replication of the NBD-Dirichlet model of buyer behaviour in order to test its generalisability by confirmation and extension (Frohlich & Dixon, 2006). Replication, and in particular differentiated replication, is an essential component of the Empirical then Theoretical (EtT) approach advocated by Ehrenberg (1994). Under this approach observed regularities in data prompt the establishment of empirically grounded theory. This theory is tested more widely under different conditions to extend the generalisability of the theory, develop it conceptually and establish boundary conditions for its application. Data and theory are interdependent, combining in a creative process to produce new understanding and knowledge. The cycle of replication under different circumstances and conceptual theory development results in an empirical generalisation, defined by Bass (1995) as:

"a pattern or regularity that repeats over different circumstances and that can be described simply by mathematical, graphic or symbolic methods".

The EtT approach is contrasted with the Theory in Isolation (TiI) approach (Ehrenberg, 1994). TiI emphasises theory first, starting with the construction of a theoretical concept before testing the new theory on a set of data. The primary difference between these approaches is in the role of replication and the importance attached to wide-ranging empirical support for the developed theory.

In EtT the criterion for testing a theory is embedded in its generalisability – how well does the model hold for different sets of data, different purchasing situations, different products (Ehrenberg, 1995). The relationship is judged to hold if there is no systematic bias and if the magnitudes of any deviations between observed and predicted data are in line with previous studies (Ehrenberg & Bound, 1993). By contrast, the generally accepted "best-fit" type models of statistical significance are tests of singularity – how well does this model fit this particular set of data.

3.3 Epistemological Location of the Research

For the past half century the philosophy of marketing science has been dominated by the debate between schools of thought that can loosely be labelled positivist and anti-positivist. Positivist ontology assumes an external reality, the true nature of which is only discovered by rigorous scientific method and empirical testing. Anti-positivism assumes that science is subjective and abandons the notion of a knowable truth in favour of creating what we come to know as "reality" within the context of the research environment. Peter and Olson (1983) describe these contrasting traditions as Logical Positivism/Empiricism and Relativism/Constructivism. Similarly "Scientific Realism" (Hunt, 1983) is contrasted with "Critical Relativism" (Anderson,

1986) yet each author bases his attack on a caricature of the other's position: the nihilism of "truthlessness" in relativism versus the singular scientific method of positivism. This retreat into opposing corners does nothing to uncover common ground between the traditions and it has been left to other writers to attempt to steer a course between these traditions, rejecting the extremes of both. Leong (1985) proposes the Lakatosian concept of sophisticated methodological falsification within a research programme (Lakatos, 1978) as a synthesis of positivism and relativism. Previous research has presented replication and the establishment of empirical generalisations in Ehrenberg's EtT approach as a Lakatosian research programme (Stern, 1994). The following sections discuss the strengths of the Lakatosian epistemology with particular regard to the accommodation of a plurality of method, progressiveness of scientific discovery and empirical testing.

3.3.1 EtT as a Research Programme

The Lakatosian research programme is similar to a Kuhnian paradigm (Kuhn, 1970) in that it sets the context and environment that govern the rules of research but differs in the extent to which it accepts multiple theories within the programme. The research programme is based around a hard core of givens accepted by the research community – fundamental assumptions and theories. Within the research programme, theories can be disproved but not proved and the refutation of a single theory is not sufficient for rejection of the entire programme.

Sophisticated methodological falsification holds that empirical testing alone is necessary but not sufficient for the refutation of a theory. Falsification can only

occur with the emergence of better theories. Research within the research programme thus proceeds according to a "positive heuristic", a set of guiding research questions and theoretical forms. The Lakatosian perspective recognises that science is a creative process, occurring within the context of a research programme established by the norms, beliefs and values of the scientific community. It demands consistency within the guiding principles of the research programme as a means of preserving scientific rationality although it makes no claim for the objectivity or "truth" of science.

The EtT approach (Ehrenberg, 1994) accepts this creative nature of the scientific process, where data and theory are interdependent. Observed regularities in data prompt the establishment of empirically grounded theory. Replications under different conditions extend the scope of the theory and develop it conceptually by establishing conditions under which the theory does not hold (Lindsay & Ehrenberg, 1993). The cycle of replication and conceptual theory confirmation and development creates the "guiding questions" that shape a positive heuristic in a research programme. The theory is judged not by how well it fits a single instance but by how generalisable it is over a range of different circumstances (Ehrenberg, 1995). The essence of replication is to find "significant sameness" across many sets of data, preferably covering a wide range of conditions (Barwise, 1995).

3.3.2 Plurality of Method – A Rich Picture

Multiple methodologies are present within current purchase and supply chain and marketing research. In the field of research into buyer behaviour these may include stochastic modelling of patterns of purchase behaviour in the aggregate

population of buyers, archival studies of the interactions between participants in long term dyadic or network relationships, ethno-methodological studies of decision making processes within organisations, quantitative or qualitative studies of individual buyer motivations, influences and experiences during the process of exchange with suppliers or collaboration with other buyers. Each of these methodologies will provide a distinctive representation of the reality of a given exchange process / purchase decision. Accepting the validity of these representations within the context of the research programme allows cross-fertilisation of ideas with observations from one methodology leading to hypotheses or insights in another. Rivalry between competing theories avoids "conceptual myopia" (Leong, 1985) - overdependence on particular methodologies.

However, the very plurality that is the strength of the Lakatosian synthesis may also be its weakness. In accommodating a variety of methodologies within a research programme the concept may be accused of trying to "have its cake and eat it". One criticism levelled at sophisticated methodological falsification is lack of focus. Kuhn (1970) expounded the benefits of theoretical monopoly – a single dominant paradigm in a discipline. By accommodating a variety of methodologies, the Lakatosian concept permits researchers to shift allegiances from one research programme and one theory to another. However as Leong points out (Leong, 1985), transitions between research programmes are not trivial. In addition the sophisticated methodological falsification framework allows for researchers to focus on a theory in the face of adverse evidence for longer than either naïve falsification or a dominant paradigm would permit. A plurality of method allows the appropriate research tool to be chosen for a

particular research question without becoming overly dependent on a particular method.

A number of further issues may arise from the existence of multiple methodologies. The distinct positions may be incommensurable, resulting in difficulties in realising the cross fertilisation that has been identified as a benefit of the approach. Differences in explanatory variables and differences in the "meaning" of terms may result in researchers talking past each other (Anderson, 1986) without finding any common ground. However Anderson's notion of a research programme bears more similarity to the monolithic single research perspective paradigm of Kuhn than Lakatos' research programme with its multiple theoretical foundations. In the Kuhnian paradigm incommensurability will eventually result in crisis and revolution or assimilation into the dominant paradigm. In the Lakatosian concept the heuristic power of the research programme provides a unifying mechanism and sound criteria as a means of evaluating concepts without threatening refutation. Taken to extremes, the plurality of methodologies implies Feyerabendian methodological anarchy. However we have already seen that the Lakatosian approach does not allow an epistemological free-for-all but rather demands that research methods are critically evaluated such that any methods adopted can be rationally defended as likely to achieve the research objectives. Indeed, the existence of alternative methodologies within the research paradigm opens the opportunity for triangulation on the basis that one method's weakness is complemented by the strengths of another (Leong, 1985).

3.3.3 Progression of Scientific Discovery

Within the sophisticated methodological falsification framework, theories are not rejected in the face of adverse evidence alone but only when a better theory is available. Lakatos claims that the heuristic power of the framework ensures the progression of science, avoiding "a mere patched up pattern of trial and error" that results in minor modifications to theories in the light of empirical anomalies (Lakatos, 2003). However it has also been noted that in an environment of falsification, competition and rivalry between theories becomes destructive (Easton, 1995a) and it may become difficult to measure scientific progress. Sophisticated methodological falsification does provide a framework for evaluation of competing theories and research programmes in terms of the progressivity they offer. "Good" science is identified by consistency of approach, empirical testing and what Easton refers to as "social acceptability" – acceptance by the scientific community within the research programme. Indeed Easton acknowledges the difference between sophisticated methodological falsification and the red in tooth and claw variety of naïve falsification, referring to the former as "falsification with a social face" (Easton, 1995a).

3.3.4 Empirical Testing

One of the main arguments against the primacy of hypothesis testing in the search for objective truth, particularly in the open systems frequently encountered in marketing and purchasing, is the difficulty in isolating dependent and independent variables i.e. ensuring that the initial assumptions and auxiliary assumptions underpinning a hypothesis are indeed subject to the constraint "all other things being equal" (Anderson, 1986). In fact this very point is made by

Lakatos who notes that there is no such thing as a "pure" observation (Leong, 1985). Within sophisticated methodological falsification there is recognition that science can never achieve absolute truth but only increasing verisimilitude within the context of the research programme and its guiding heuristic of "relevant technique". Empirical testing is a necessary but not sufficient reason for refutation and falsification cannot occur without the emergence of a better theory. The importance of replication studies within EtT overcomes some of the problems associated with "pure" observations by testing the theory on different samples, using different data collection methods in different industries, times and locations and by involving different observers to reduce single observer bias (Wright & Kearns, 1998).

The sophisticated methodological falsification approach has been shown to provide a synthesis of positivism and relativism and a framework for marketing research that recognises and accommodates the plurality of method in common use in the current study of marketing and buyer behaviour in particular. In a field of research as complex and broad as marketing and purchasing it seems reasonable to assume that dogmatic adherence to a single research method will not be sufficient to uncover all elements of what Hunt has described as "the behavioural science that seeks to explain exchange relationships" (Hunt, 1983). In the context of a research programme with positive heuristic power, rival theories can co-exist, inform and complement each other. The researcher is free to choose those methods that will be most effective in uncovering new findings, provided that the chosen methods can be defended within the normative guidelines of the research programme, will lead to the discovery of novel findings and will be accepted within the scientific community.

3.4 Research Study Design

The current research aims to investigate the behaviour of purchasers in a collaborative procurement environment, in particular to seek to identify whether the behaviours follow any regular pattern, if the observed patterns can be described and predicted using a robust model of buyer behaviour, the NBD-Dirichlet, and whether such modelling can be used to inform management decision making in a collaborative purchasing context.

The research is a differentiated replication of the NBD-Dirichlet model of buyer behaviour into conditions quite different to those encountered in other Dirichlet studies. In this case the purchasing situation is procurement of surgical supplies in a public sector collaborative procurement organisation. Frohlich and Dixon (2006) observed that the contribution of a replication depends on the outcomes with an important contribution resulting from refutation or extension of the original study. They categorise replications based on whether the data used is similar or different and whether the methods used are similar or different. A similar distinction is drawn by Lindsay and Ehrenberg (1993) when they discuss "close" replications (similar data and methods) and "differentiated" replications (different data and/or different methods).

The following sections of this chapter set out the design of the replication study, including the sampling frame (panel size and structure), required data and data sources, data handling and analysis and parameterisation of the Dirichlet model. The method used to determine the Dirichlet parameters follows the method set out in Ehrenberg (1988) and Goodhardt et al (1984) and coded in the BUYER software package (Uncles, 1989). The Dirichlet parameters are calculated

manually from purchase occasion data and compared to the BUYER outputs to validate the software performance. Purchase patterns and performance measures are predicted using the model and these are then compared to observed measures from the base period and a holdout sample to determine the extent to which the model holds. The method is illustrated by use of worked examples using data acquired from a single NHS Trust in a pilot study.

The pilot study is conducted in a single hospital trust to identify suitable product categories, to determine the availability of useable information and to test the operationalisation of the model using the data for the selected categories. When suitable categories are identified, data related to the selected categories is collected from the collaborative procurement hub in order to perform the longitudinal analysis. The pilot study is reported in Chapter 5 and the longitudinal analysis of collaborative hub data is reported in Chapters 6 and 7.

3.4.1 Data Sources

Dirichlet analyses are typically carried out on data collected from established consumer panels. Panel data is effectively a purchase history for a particular purchaser and product i.e. the number of occasions that an individual panel member purchased the product from a particular supplier in a specific time period. In an organisational context, such panel data is not generally available and historic purchase data must be collected from secondary sources (company records) or primary sources (direct from individual purchasers). Collaborative procurement organisations act as aggregators of data as well as purchase volumes and their purchase order records are a suitable substitute for panel data.

For this research the National Health Service (NHS) has provided limited access to purchasing data from one hospital trust and one Collaborative Procurement Hub (CPH). The complexity of the procurement function in the NHS, including the relationships between the CPH and individual hospitals, the influence of clinicians and the constraints of public-sector procurement make this a highly differentiated replication and a new application of the NBD-Dirichlet in the purchasing discipline. The NHS Purchasing & Supply Agency (PASA) has a research function and has been very supportive in the current research. A detailed description of procurement in the NHS is given in the next chapter.

3.4.1.1 Pilot Study

Expenditure in the NHS covers a wide variety of product categories. To identify categories of interest for the research and to determine the availability and form of the data available, a pilot study was carried out in a single hospital trust. A suitable category should be easily identifiable in the data, either from category coding or a clear product description and there should be sufficient purchasing activity and variety in terms of suppliers and requisitioners to make the analysis meaningful. In order to research the dynamic behaviours before and after an intervention, there should also have been some active purchasing management intervention in the category.

The pilot data collected was a complete download of all the requisitions raised by a single NHS hospital trust during the month of May 2008. This included the following data items:

PO_No — The Purchase Order number is the unique identifier for the purchase occasion. Where a purchase order includes

	several line items, these are aggregated and treated as a single purchase occasion.
Supplier	The Supplier named in the Purchase Order is the supplier chosen for that particular purchase occasion.
Order Date	The Order Date is the date on which the Purchase Order was raised. This is used to determine the chronological sequence of purchases in order to identify repeat purchasing behaviour.
Description	The Description is usually a free text field where the requisitioner describes the goods or services to be purchased. This is important when screening the data as item codes may be missing or incorrect and the description can then be used to validate the coded data.
Charge Account	The Charge Account is the cost centre or department that is making the purchase. The cost centre is often the lowest organisational resolution in the analysis and is usually used as the Purchaser in the analysis.
Category	The Category is the coding used for the purchase category and is used to isolate specific category codes for analysis. Items may be miscoded and codes are checked against item descriptions to ensure consistency.
Req_Preparer	The Requisition Preparer is the individual who raised the actual requisition.

The data set covered 1921 individual purchase orders with 4692 line items. There were 136 requisitioners, 552 suppliers and 284 distinct purchase

categories. The number of suppliers in each category ranged from 1 to 40 and the number of orders placed in each category ranged from 1 to 119. Categories with more than 20 purchases in the month are tabulated in Table 3.1 to assist identification of a suitable category.

A single purchase category, F.FX.FXC, coronary stents, was chosen for analysis. This was chosen because it provided a sample frame with a reasonable number of requisitioners (14), suppliers (7) and purchase orders (77) in the time period. In addition, the category was well defined, in contrast to other categories where the line item descriptions covered a wide range of items with some items appearing in more than one category. The relatively high purchase frequency (77 purchase orders in one month) allows the model to be parameterised and tested even though the time period of analysis is short. During the pilot study, discussions with representatives from NHS PASA, CPHs and the trust that provided the pilot data also identified coronary stents as a significant expenditure for the NHS and the subject of much purchasing attention in recent years.

Table 3.1 **Purchaser orders by category (single hospital trust)**

Category	Number of suppliers in category	Number of Orders
F.FX.FXB	24	119
F.FX.FXD	10	80
F.FX.FXC	**7**	**77**
F.FC.FCC	40	76
F.FB.FBF	28	69
F.FD.FDA	31	61
F.FY.FYX	29	61
H.HB.HBB	29	59
H.HX.HXB	29	49
K.KB.KBD	27	49
F.FQ.FQA	5	43
H.HH.HHB	25	42
F.FY.FYZ	24	38
F.FX.FXH	5	38
I.IK.IKB	18	35
F.FS.FSP	9	34
F.FB.FBU	22	32
H.HF.HFB	5	32
F.FB.FBE	15	28
F.FB.FBZ	11	27
P.PZ.PZE	14	26
F.FX.FXM	6	26
F.FQ.FQX	4	25
F.FX.FXU	13	23
K.KM.KMP	11	22
F.FC.FCB	15	21
F.FY.FYY	16	20

3.4.2 Sample Frame

The analysis described in the following sections follows the method set out by Ehrenberg (1988). The unit of analysis for the research is the purchase occasion. The data required for the research is a continuous longitudinal record of purchase occasions for a specific product category, detailing when the purchase was made, who made the purchase and what supplier was chosen.

Two considerations are important in determining the sample frame.

(i) The period of time over which the analysis is made.

This is determined by the typical length of time between purchases. For example if the average inter-purchase time is three months, the sample should extend over several three month periods to permit analysis of repeat purchase behaviour. The data should be collected over a period of time long enough to use part of the data to fit the model and the remainder as a hold out sample for testing the fit of the predictions.

(ii) The number of purchasers in the sample.

The population being studied is limited to those who purchase the specific product category, rather than all potential purchasers in the organisation. Analysis of continuous purchase records allows the whole population of category purchasers to be analysed.

The population of purchasers is an important measure that is indirectly used to parameterise the Negative Binomial Distribution through the proportion of the population that do not purchase from a specific supplier (see Section 3.4.3). This is also influenced by the period of time over which the analysis is made.

Using purchase order data rather than panel data means that over the entire period of the continuous data collection, all of the population will have made at least one purchase. While this means that the sample is actually a census of the whole population of buyers, the proportion of non-buyers will be zero.

The entire purchasing population will include a number of "never buyers" or "hard core non-buyers" who will never raise a requisition for a coronary stent because they do not work in the relevant departments. To parameterise the model and avoid the misleading results that may arise from too high a proportion of "never buyers" (Morrison, 1969; Dunn et al, 1983), a relevant purchasing population is assumed to be between the entire population of requisitioners and those who buy coronary stents during the period of analysis.

Several assumptions underpin the Dirichlet model. In addition to the formal distributional assumptions outlined in Chapter 2, it is assumed that the market is stable and non-partitioned. A check should be made that the Dirichlet assumptions hold for the particular sample, for example by comparing the stability of supplier market shares and average purchase rate over the period of analysis. Too short a sample time may introduce discrepancies if the period of analysis is too close to the average interpurchase time (Ehrenberg, 1988); too long a sample time may mask the existence of dynamic situations.

The distributional assumptions can also be tested for the sample although in practice the number of successive time periods is usually insufficient to fully validate the long run purchase probabilities of individual buyers. For this analysis the assumptions underpinning the NBD part of the NBD-Dirichlet

model will be tested by examining the fit between calculated and observed distribution of purchases (Ehrenberg, 1988) as shown in Figure 3.1.

Buyer	*Successive Time Periods*								
	1	*2*	*3*	*4*	*5*	*6*	…	*Long Run Average*	*Distribution*
A	*x*	*x*	*x*	*x*	*x*	*x*		μ_A	*Poisson*
B	*x*	*x*	*x*	*x*	*x*	*x*		μ_B	*Poisson*
C	*x*	*x*	*x*	*x*	*x*	*x*		μ_C	*Poisson*
D	*x*	*x*	*x*	*x*	*x*	*x*		μ_D	*Poisson*
…									*Poisson*
Distribution	*NBD*	*NBD*	*NBD*	*NBD*	*NBD*	*NBD*		*Gamma*	

Figure 3.1 Distributional assumptions of the NBD-Dirichlet

Table 3.2 presents the tabulated pilot study data. It shows the characteristic NBD form with most buyers making relatively few (or no) purchases per week and a few buyers making a larger number of purchases.

The remaining assumptions underpinning the NBD-Dirichlet model, namely that supplier choice probabilities can be described by a multivariate beta distribution (the Dirichlet), that buyers have their own, fixed supplier choice probabilities and that these supplier choice probabilities are independent of purchase frequency, are also difficult to validate in isolation. The independence of supplier choice probabilities and purchase frequency can be tested by examining supplier market shares for light, medium and heavy category buyers – if the assumption holds, these should be the same irrespective of being a light or heavy purchaser. The other assumptions are tested by examining the fit between calculated and observed distribution of purchases.

The remainder of this chapter uses the pilot data to demonstrate the mechanics of the calculations required to operationalise, test and apply the NBD-Dirichlet model. The complete pilot data analysis is presented in Chapter 5.

Table 3.2 Weekly purchases by buyer

Requisitioner	Successive Time Periods (weeks)				Weekly Average
	1	2	3	4	
A	1	10	6		4.3
B	5	3	1	5	3.5
C			3	6	2.3
D	3	3	2		2.0
E		3	2		1.3
F		1	1	2	1.0
G		3			0.8
H		2	1		0.8
I	1		1		0.5
J				1	0.3
K				1	0.3
L		1			0.3
M				1	0.3
N			1		0.3

3.4.3 Data Analysis

The data required to fit the model for a chosen product category in a specific time period are as follows:

(i) The proportion of the population buying the category at all (B)

(ii) The average number of purchase occasions recorded for those in the population who purchase the category at all (W)

(iii) For each supplier (i), the proportion of the population buying from that supplier at all (b_i)

(iv) For each supplier (i), the average number of purchase occasions recorded for those in the population who purchase from that supplier at all (w_i)

The minimum purchase record data required for the analysis will include the date of each purchase, the product category (if the records cover multiple categories), the supplier and the purchaser or requisitioner (may be a department although analysis at the individual purchaser level can give additional insights into purchasing behaviour). These data are usually readily available from organisational purchasing systems. The purchase data are for the number of purchase occasions, not for volume of product or amount of expenditure.

In practice, raw purchasing data often contains errors and omissions, typically unclear or missing category or product descriptions and multiple variations of a supplier's name. The data must be screened to remove these discrepancies and arrive at a common set of category definitions and supplier names.

When the data has been screened the first step in the analysis is to tabulate the data to determine the appropriate timescale for analysis. This will depend on the purchase frequency of the product category. For example, relatively fast moving categories may be analysed in periods of 2-4 weeks, durable, infrequently purchased capital equipment items may require analysis over several years. This initial tabulation also starts to show up preliminary patterns, for instance light and heavy purchasers, duplication of purchase, where a buyer fulfils their requirements for the product category with two or more suppliers, and high and low market share suppliers.

At this stage the Dirichlet assumptions can start to be tested. By plotting market share for each supplier and average purchase frequency in each time period the stability assumption can be tested. If an individual's purchase patterns (i.e. the propensity to purchase and the propensity to choose a particular supplier on that purchase occasion) are constant, then the market shares of individual suppliers can be assumed to be constant from one period to another.

The other Dirichlet assumption relates to non-partitioning, i.e. there are no segments that exhibit a preference for a subset of the suppliers. Sharp & Driesener (2000) have demonstrated that violation of the Dirichlet assumption on non-partitioning does lead to deviation between the predicted and observed performance measures. Again, a review of the tabulated data can identify niche suppliers (lower than expected penetration, higher than expected purchase frequency) that are used relatively heavily by a small proportion of buyers (Kahn et al, 1988).

3.4.4 Fitting the Model

For a given product category, the model is parameterised using two input measures for each supplier in the category and for the category as a whole. If the model was an exact fit, any single supplier could be used to determine the parameters. However, in practice this is rarely the case and each of the leading suppliers are used to determine the model parameters in turn. The parameters are then combined as a weighted average, using the supplier market share as the basis for weighting.

For the chosen analysis period (week, month, quarter, year …), the following measures are determined for each supplier:

The Penetration (b) is the proportion of the population that buys from the supplier at least once in a given time period.

$$Penetration\ (b) = \frac{Number\ buying\ at\ least\ once}{Total\ number\ of\ \ potential\ buyers}$$

The Purchase Frequency (w) is the number of occasions on which the average buyer of the particular supplier bought from that supplier during a given time period.

Table 3.3 shows summary statistics for an average two-week period. It can be seen that the average requisition frequency is quite similar across all the suppliers although the market shares differ. The exception is the "Others" composite supplier where the combination of low market share and low purchase frequency is the frequently observed "Double Jeopardy" pattern where small suppliers not only have fewer purchasers but these purchasers also purchase less frequently.

Table 3.3 Summary statistics (average two weekly)

Supplier	Number of Requisitions	Number of Requisitioners	Requisition Frequency	Penetration	Market Share
MEDTRONIC	12.0	6.5	1.8	16.3%	34.3%
BOSTON	11.5	6.0	1.9	15.0%	32.9%
ABBOTT	8.0	4.5	1.8	11.3%	22.9%
OTHER	3.5	2.5	1.4	6.3%	10.0%
ANY	35.0	10.5	3.3	26.3%	100.0%

In this case the relevant population is assumed to be 40. ANY is the combined data for the sub-category, regardless of supplier. The number of requisitioners for ANY supplier is 10.5, compared to the simple sum of buyers of all products

which is 19.5. This shows that several requisitioners split their purchases between more than one supplier in the time period.

The method of fitting the model follows the procedures in Goodhardt et al. (1984) and Ehrenberg (1988).

(i) Fitting the NBD

The NBD is derived from expanding the binomial expression $(1-\frac{m}{m+k})^{-k}$ to determine the probability p_r of observing r purchases where r is a non-negative integer (0, 1, 2, 3, 4, …). The probability p_r is given by the following expression

$$p_r = \frac{(1+\frac{m}{k})^{-k}\Gamma(k+r)}{\Gamma(r+1)\Gamma(k)}\left(\frac{m}{m+k}\right)^r \qquad [1],$$

where m is the average number of purchases per individual for the whole population and k is the exponent of the NBD.

m is readily determined from the sample data, either directly or from the product of the penetration and the purchase frequency ($m = b \times w$).

To determine k, Ehrenberg (1988) proposes a method utilising the number of non-buyers. The observed proportion of non-buyers p_0 is equated to its expected value.

From expression [1] and setting $r = 0$, the expected value for p_0 becomes

$$p_0 = (1+\frac{m}{k})^{-k}$$

The observed proportion of non-buyers can be determined from the sample, equated to the expected value and the resulting equation solved for *k*. This equation cannot be solved directly and requires an iterative solution.

Table 3.4 presents the parameters for the pilot data set, calculated using the method described above and using average two-weekly data.

Table 3.4 Calculated NBD parameters

Supplier	Average Number of Purchases (w)	Penetration (b)	p_0 = 1-b	m = b.w	k
MEDTRONIC	1.8	16.3%	83.8%	0.30	0.182
BOSTON	1.9	15.0%	85.0%	0.29	0.155
ABBOTT	1.8	11.3%	88.8%	0.20	0.125
OTHER	1.4	6.3%	93.8%	0.09	0.111
ANY	3.3	26.3%	73.8%	0.88	0.166

(ii) Fitting the Dirichlet

The Dirichlet distribution assumed to describe the heterogeneity in supplier choice probabilities is a multivariate Beta distribution given by the joint density function (Goodhardt et al, 1984).

$$Cp_j^{\alpha_j - 1} \ldots p_g^{\alpha_g - 1}$$

where,

$$p_j \geq 0, \sum p_j = 1$$

$$C = \frac{\Gamma(S)}{\Pi(\Gamma \alpha_j)}$$

$$S = \sum \alpha_j \, , \alpha_j > 0$$

p_j is the probability that an individual chooses supplier *j* from *j = 1, … , g* suppliers and α_j is the Beta distribution parameter for supplier *j*.

The Dirichlet S parameter is the sum of the alphas over all the individuals and suppliers.

Ehrenberg (1988) sets out a procedure to estimate the Dirichlet parameter *S*. Using Equation 1 above, the *m* and *k* parameters determined for the ANY "supplier" in the previous section are used to generate a theoretical Negative Binomial Distribution (NBD) such that the probabilities of an individual making 0, 1, 2, 3, … purchases of the whole product category in the time period can be calculated.

The NBD is an infinite series so the calculation must be truncated and the tail of the NBD approximated. This tail consists of very heavy buyers and is hence numerically important. The truncation procedure detailed in Goodhardt et al (1984) approximates the tail by assuming that the sum of the tail probabilities can be divided over two values *n'* and *n'+1*. Purchase proportions ($p_{n'}$ and $p_{n'+1}$) and number of purchases ($n'p_{n'}$ and $(n'+1)p_{n'+1}$) can be calculated. *n'* is determined by setting the sum of the number of purchases at *n'* and *n'+1* equal to the residual tail i.e. the total purchases accounted for by those buying more times than the number of purchases at which the distribution was truncated.

If the NBD is truncated at *n**, then

$$p_{n'} + p_{n'+1} = 1 - \sum_{0}^{n^*} p_n = P_R \qquad [2]$$

$$n' p_{n'} + (n'+1) p_{n'+1} = M - \sum_{1}^{n^*} n p_n = Q_R \qquad [3]$$

where *M* is the mean number of category purchases per member of the population (i.e. *m* for the ANY "supplier"). These equations are used to determine *n'* and *n'+1*.

This is demonstrated in the following worked example, using the pilot data. First the NBD proportions of the population buying the product category *n* times are calculated using Equation 1. The calculation must be truncated at some point and in the example shown, this is when the residual cumulative probability is greater than 0.9975 i.e. when n* is 18.

Using Equation 2,

$$p_{n'} + p_{n'+1} = 1 - \sum_{0}^{n^*} p_n = P_R = 1 - 0.9978 = 0.0022$$

And Equation 3,

$$n' p_{n'} + (n'+1) p_{n'+1} = M - \sum_{1}^{n^*} n p_n = Q_R = 0.8749 - 0.8233 = 0.0516$$

where *M* is the value for *m* for the ANY "supplier" (Table 3.4).

P_R is multiplied by *n'* and subtracted from Q_R to give

$$p_{n'+1} = Q_R - n' P_R ,$$

which can be divided by P_R to give,

$$\frac{p_{n'+1}}{P_R} = \frac{Q_R}{P_R} - n'$$

n' is the integral part of $\frac{Q_R}{P_R}$ and thus

$p_{n'+1} = P_R$ * (non-integral part of $\frac{Q_R}{P_R}$)

Using the pilot data,

$$\frac{Q_R}{P_R} = \frac{0.0516}{0.0022} = 23.4545, \text{ so } n' = 23$$

$p_{n'+1} = p_{24} = 0.0022 * 0.4545 = 0.0010$

$p_{n'} = p_{23} = P_R - p_{n'+1} = 0.0022 - 0.0010 = 0.0012$

This approximation to the tail is shown in Table 3.5.

Table 3.5 Calculated proportion of population buying the category n times

n	Proportion Buying P_n	Cumulative Proportion ΣP_n	Purchases nP_n	Cumulative Purchases $n\Sigma P_n$
0	0.7375	0.7375	0.0000	0.0000
1	0.1028	0.8403	0.1028	0.1028
2	0.0504	0.8906	0.1007	0.2035
3	0.0306	0.9212	0.0917	0.2952
4	0.0203	0.9415	0.0813	0.3765
5	0.0142	0.9558	0.0712	0.4478
6	0.0103	0.9661	0.0619	0.5096
7	0.0076	0.9737	0.0535	0.5631
8	0.0058	0.9795	0.0460	0.6091
9	0.0044	0.9839	0.0395	0.6486
10	0.0034	0.9872	0.0338	0.6824
11	0.0026	0.9899	0.0289	0.7112
12	0.0021	0.9919	0.0247	0.7359
13	0.0016	0.9935	0.0210	0.7569
14	0.0013	0.9948	0.0179	0.7748
15	0.0010	0.9958	0.0152	0.7900
16	0.0008	0.9966	0.0129	0.8030
17	0.0006	0.9973	0.0110	0.8140
18	0.0005	0.9978	0.0093	0.8233
23	0.0012	0.9990	0.0276	0.8509
24	0.001	1.0000	0.024	0.8749

The estimation of the Dirichlet parameter is by an iterative procedure, using non-buyers of the supplier to fit the model in the same way as for the NBD. For each frequency of buying the product category, non-buyers of the supplier are estimated from the product of the probability of making *n* category purchases (p_n) and an estimated probability of not buying supplier *j*, having made *n* purchases ($p'_{(0|n)}$). $p'_{(0|n)}$ is estimated using a trial value of *S* which is denoted *S'*. Ehrenberg (1988) introduces two dummy variables, *c'* and *d'* to simplify the calculations.

$$c' = S' - \frac{m \times S'}{M}$$

$$d' = \frac{c'}{S'}$$

The initial estimate of p'_0 is estimated from the NBD p_0 and p_1

$$p'_0 = p_0 + (p_1 \times d')$$

Using the pilot data, data for Abbott (Table 3.4), a starting value for *S'* = 2 and p_0 and p_1 from Table 3.5.

$$c' = 2 - \frac{(0.2 \times 2)}{0.8749} = 1.5428$$

$$d' = \frac{1.5428}{2} = 0.7714$$

$$p'_0 = 0.7375 + (0.1028 \times 0.7714) = 0.8168$$

Next p_2 is used to generate a new estimate of p'_0. The value of *d'* must be revised for each *n* up to *n'* and *n'+1*, the approximations for the NBD tail.

$$d'_{new} = d'_{old} \times \left(\frac{c' + (n-1)}{S' + (n-1)}\right)$$

$$p'_0 = p'_{old} + (p_2 \times d'_{new})$$

Thus, for $n = 2$

$$d'_{new} = 0.7714 \times (\frac{1.5428 + (2-1)}{2 + (2-1)}) = 0.6538$$

$$p'_0 = 0.8168 + (0.0504 \times 0.6538) = 0.8498$$

and for $n = 3$

$$d'_{new} = 0.6538 \times (\frac{1.5428 + (3-1)}{2 + (3-1)}) = 0.5791$$

$$p'_0 = 0.8498 + (0.0306 \times 0.5791) = 0.8675$$

The final estimated value for p'_0 is compared to the observed value for non-buyers of the supplier. A revised *S''* is estimated and the procedure repeated. If p'_0 is less than p_0, a larger value for *S* is used, if smaller then a smaller *S* is used. The iterations continue until the difference between the calculated and observed values of p_0 is within the desired limits.

The iteration is summarised in Table 3.6 below, using $p_0 = 0.8875$ for Abbott (from Table 6). If p'_0 becomes greater than p_0 before reaching *n'* and *n'+1* the calculation can be stopped and a new value for S' chosen. The value of n reached in each stage is shown in Table 3.6.

Table 3.6 Summary of iterations to determine S for Abbott

S'	p'_0	$p'_0 - p_0$	n
2.0	0.8897	0.0022	6
4.0	0.8880	0.0005	8
6.0	0.8880	0.0005	13
8.0	0.8863	-0.0012	24
6.9	0.8875	0.0000	24

This repeated for the other suppliers and the overall Dirichlet parameter calculated from a weighted average of the supplier S_j using the market shares of each supplier (m_j).

$$S = \frac{\sum \frac{S_j m_j}{M}}{\sum \frac{m_j}{M}}$$

If the model fits well, all the individual supplier S_j values should be similar. If this is not the case, one or more of the outlying supplier Dirichlet parameters may be excluded from the estimate of the overall parameter.

The parameters calculated from the pilot data are presented in Table 3.7. The iteration for Medtronic did not converge and no value for S_j was calculated. It can be seen from Table 3.7 that there is a wide variation in the individual S_j values, suggesting that the model is far from an exact fit.

Table 3.7 Dirichlet parameters for pilot data

Supplier	S_j	m_j	m_j/M	$S_j m_j/M$
Medtronic		0.30	0.34	
Boston	18.2	0.29	0.33	5.98
Abbott	6.9	0.20	0.23	1.58
Others	15.3	0.09	0.10	1.53

If Medtronic and Abbott are excluded from the calculation for the overall S parameter, the value of S is estimated to be 17.5.

Several computer programmes have been developed to calculate the Dirichlet parameters. These include BUYER (Uncles, 1989) and DIRICHLET (Kearns, 2009). A systematic comparison of BUYER and DIRICHLET concluded no bias in either software solution, allowing confidence in the selection of either

(Kearns & Lewis, 2000). The BUYER programme permits use of tabulated purchase data and is used in the current research. The outputs of the BUYER software have been checked against the manual calculation using the methodology described above. The outputs from the manual calculations and the BUYER software are compared in Table 3.8. The BUYER software forces a value for the Medtronic *S* parameter, resulting in a much higher estimate for the overall *S*. The other calculated parameters are similar and any differences may be attributed to differences in the truncation procedures used. The BUYER software allows the overall S to be manually changed in the event that one or more of the individual S_j values appears irregular.

Table 3.8 Comparison of calculated S parameters for pilot data

Supplier	Manual	BUYER
Medtronic		50
Boston	18.2	17.13
Abbott	6.91	6.87
Others	15.3	14.9
Overall	17.5	25.82

3.4.5 Using the Model

Having fitted the NBD-Dirichlet model, it is used to predict a range of brand performance measures (Ehrenberg et al, 2004) for the time period of analysis and for time periods of different length.

Typical measures include:

(i) Penetration of purchasers, i.e. the proportion of the population buying from that supplier

(ii) Light and heavy purchasers, i.e. percentage of purchasers buying from the supplier once and five times (say) in the time period

(iii) Average number of purchases from the supplier per buyer (of that supplier)

(iv) Percentage of buyers of a particular supplier who purchase again from that supplier in the next period.

(v) Average number and distribution of the numbers of purchases of the category by buyers of a specific supplier

(vi) Share of category requirements, i.e. the share of requirements that buyers of a particular supplier actually meet from that supplier

(vii) Percentage of sole buyers, i.e. buyers who meet all their category requirements with a single supplier

(viii) Rate of purchase of sole buyers

(ix) Duplication of Purchase, i.e. what other suppliers are used by buyers of a particular supplier. For example 25% of buyers from Supplier *i* also purchase from supplier *j*.

Although all of these measures are determined using the BUYER software, the calculations for each of the measures are described below. These are as presented in Ehrenberg (1988).

For each supplier, the matrix of Dirichlet proportions is developed. A typical matrix is shown below in Figure 3.2 detailing the proportions of the population purchasing the category $n = 0, 1, 2, 3$ or more times and the proportion of those purchases that are made with a particular supplier. n^*, n', $n'+1$ are the numbers of category purchases used in the truncation procedure as defined in the previous section and $r = 0,1,2,3\ldots r'-1, r', r'+1$ for the single supplier.

The proportions making 0,1,2,3,… purchases for the product category are determined from the category NBD as defined in Section 3.4.4 (Equation 1). This is the row P_0, P_1, P_2 … in Table 3.2 below. The main part of the table is the matrix of the proportion of the population making *r* purchases of a particular supplier, given *n* purchases of the product category.

		n = 0, 1, 2, 3, … purchases of the Product Category								
	Numbers	*0*	*1*	*2*	*3*	…	*n**	*n'*	*n'+1*	*Total*
	Proportions	P_0	P_1	P_2	P_3	…	P_{n^*}	$P_{n'}$	$P_{n'+1}$	*1.0*
	0	$p_{0\|0}$	$p_{0\|1}$	$p_{0\|2}$	$p_{0\|3}$	…	$p_{0\|n^*}$	$p_{0\|n'}$	$p_{0\|n'+1}$	p_0
	1		$p_{1\|1}$	$p_{1\|2}$	$p_{1\|3}$	…	$p_{1\|n^*}$	$p_{1\|n'}$	$p_{1\|n'+1}$	p_1
Purchases	2			$p_{2\|2}$	$p_{2\|3}$	…	$p_{2\|n^*}$	$p_{2\|n'}$	$p_{2\|n'+1}$	p_2
of a single	…					…				…
supplier	…					…				…
	r'-1						$p_{r'-1\|n^*}$	$p_{r'-1\|n'}$	$p_{r'-1\|n'+1}$	$p_{r'-1}$
	r'							$p_{r'\|n'}$	$p_{r'\|n'+1}$	$p_{r'}$
	r'+1								$p_{r'+1\|n'+1}$	$p_{r'+1}$

Figure 3.2 Table of Dirichlet proportions

The individual cells in the matrix are calculated using the recurrence formula presented by Ehrenberg (1988),

$$p_{0|n} = p_{0|n-1} \times \left(\frac{\beta + n - 1}{\alpha + \beta + n - 1} \right) \times \left(\frac{P_n}{P_{n-1}} \right)$$

where,

$$\alpha_i = S \times \left(\frac{m_i}{M} \right), \; S = \alpha_i + \beta_i$$

using the Dirichlet parameter, *S*, as calculated in the previous section.

Putting the initial value of $p_{0|0}$ equal to P_0, the next value $p_{0|1}$ can be calculated. This value can in turn be used to calculate $p_{0|2}$ and so on.

The remaining entries are calculated using the recurrence formula,

$$p_{r|n} = \frac{n-r+1}{r} \times \left(\frac{\alpha + r - 1}{\beta + n - r} \right) \times p_{r-1|n}$$

The starting value $p_{0|1}$ is obtained from the previous row of the matrix and used to calculate $p_{1|1}$. $p_{0|2}$ is used to calculate p1|2 and so on. This is repeated for all r and n. The values to the left of the diagonal are equal to zero (i.e. the probability of buying twice from a particular supplier when only one category purchase is made).

When the table is complete, the following arithmetic checks should be made.

$$\sum_{n=0}^{n'+1} p_n = 1.0$$

$$\sum_{r=0}^{r'+1} p_r = 1.0$$

$$\sum_{r=1}^{r'+1} r p_r = BW\left(\frac{\alpha_i}{S} \right)$$

$$\sum_{r=0}^{r'+1} p_{r|n} = p_n$$

A section of the Dirichlet proportion table for Abbott is presented in Table 3.9 below.

3.4.5.1 Calculating the Supplier Performance Measures

Single supplier measures can be calculated from the NBD part of the model (using the parameter k as described in the previous section) or from the theoretical frequency distribution as shown in the last column of Table 3.9. The

calculation of multi-supplier measures requires use of the full NBD-Dirichlet model.

Table 3.9 Section of Dirichlet proportions matrix (Abbott)

Numbers	n	0	1	2	3	4	5	6	Total
Proportions	pn	0.73750	0.10277	0.05036	0.03056	0.02034	0.01425	0.01031	1.000
Purchases of Abbott	0	0.73750	0.07927	0.03045	0.01469	0.00787	0.00448	0.00267	0.882
	1		0.02349	0.01680	0.01137	0.00763	0.00513	0.00346	0.076
	2			0.00311	0.00392	0.00369	0.00311	0.00247	0.024
	3				0.00058	0.00102	0.00120	0.00120	0.010
	4					0.00013	0.00029	0.00041	0.004
	5						0.00003	0.00009	0.002
	6							0.00001	0.001
	7								0.001
	8								0.000
	9								0.000
	…								…
Total		0.73750	0.10277	0.05036	0.03056	0.02034	0.01425	0.01031	1.000

3.4.5.1.1 Penetration

The penetration can be derived from the value of p_0 in the theoretical frequency distribution for the particular supplier.

$$b = 1 - p_0$$

In the specified time period, p_0 is used to fit the model, but the NBD can be used to calculate penetrations in time periods of different length.

$$b_T = 1 - \left(1 + \frac{Tm}{k}\right)^{-k}$$

b_T is the penetration in the new time period.

T is the new time period based on the observed time period. For example, if the original data was based on a 4 week period and the penetration in 12 weeks was required, $T = 3$.

Using the pilot data (two week base period) the expected theoretical (T) penetration in 1 week (T = 0.5) and 4 weeks (T = 4) can be calculated and

compared to the observed (O) data as shown in Table 3.10. The correlation coefficient and the Mean Absolute Deviation between the observed and theoretical performance are calculated as summary goodness of fit measures. These are discussed further in Section 3.4.6.

Table 3.10 Penetration growth

	1 week		4 week	
Supplier	**O**	T	**O**	T
MEDTRONIC	**9.4%**	10.4%	**22.5%**	23.3%
BOSTON	**10.0%**	9.7%	**25.0%**	21.3%
ABBOTT	**7.5%**	7.1%	**15.0%**	16.4%
OTHER	**3.8%**	3.6%	**10.0%**	10.0%
Average Supplier	**7.7%**	7.7%	**18.1%**	17.8%
Correlation, r	0.98		0.95	
Mean Absolute Deviation	0.5%		1.5%	

3.4.5.1.2 Average Number of Purchases

The average number of purchases can be calculated from the market share and penetration for that particular supplier.

$$w = \frac{m}{b}$$

Table 3.11 Purchase frequency in different time periods

	1 week		4 week	
Supplier	**O**	T	**O**	T
MEDTRONIC	**1.6**	1.4	**2.7**	2.6
BOSTON	**1.4**	1.5	**2.3**	2.7
ABBOTT	**1.3**	1.4	**2.7**	2.4
OTHER	**1.2**	1.2	**1.8**	1.8
Average Supplier	**1.4**	1.4	**2.3**	2.4
Correlation, r	0.82		0.80	
Mean Absolute Deviation	0.1		0.2	

As the market shares are assumed to be stationary, the average frequency of buying in different length time periods can be simply determined from the calculated penetrations in different time periods. The observed and theoretical purchase frequencies for 1 week and 4 weeks are shown in Table 3.11.

3.4.5.1.3 Light and heavy purchasers

The percentage of purchasers buying from the supplier once, twice and five times (say) in the time period can be determined from the theoretical frequency distribution for the supplier, either from the Dirichlet matrix (Table 3.9) or calculated directly from the NBD parameters *m* and *k* (Table 3.4) using Equation 1 in Section 3.4.4. Table 3.12 presents the distribution for Abbott. The distribution derived from the NBD differs from the Dirichlet because the individual supplier NBD parameters are used rather than the weighted average Dirichlet parameter.

Table 3.12 Light and heavy purchasers

Number of purchases	Proportion of population making 0, 1, 2, 3 … purchases		
	Observed	NBD	Dirichlet
0	**0.8875**	0.8875	0.8816
1	**0.0375**	0.0682	0.07562
2	**0.0625**	0.0236	0.0239
3	**0.0125**	0.0103	0.0097
4	**0**	0.005	0.0044
5+	**0**	0.0055	0.0048

Note that the proportion of the population making no purchases is used in fitting the NBD.

3.4.5.1.4 Repeat purchasing

The NBD can be used to determine what proportion of buyers of the product in one period do so again in the next period and the purchase frequency of these repeat buyers. When the proportion of repeat buyers is known, the proportion of lapsed buyers (i.e. those who buy in Period 1 but not in Period 2) and new buyers (those who buy in Period 2 but not in Period 1) can be calculated.

$$b_R = 1 - 2\left(1 + \frac{m}{k}\right)^{-k} + \left(1 + \frac{2m}{k}\right)^{-k}$$

where b_R is the proportion of population who are repeat buyers in two successive equal time periods.

$$m_R = m \times \left(1 - \left(1 + \frac{m}{k}\right)^{-k-1}\right)$$

$$w_R = \frac{m_R}{b_R}$$

where w_R is the average purchase frequency per repeat buyer.

The proportion of the population who are new buyers (b_N) is given by the difference between the proportion of buyers and the proportion of repeat buyers.

$$b_N = b - b_R$$

Under stationary conditions the proportion of buyers (b) in Period 1 is the same in Period 2. Hence the proportion of the population who are lapsed buyers (b_L) is also given by the difference between the proportion of buyers and the proportion of repeat buyers and is equal to b_N.

The average purchase frequency of new or lapsed buyers (w_N, w_L) is given by the formula,

$$m_N = m \times \left(1 + \frac{m}{k}\right)^{-k-1}$$

$$w_N = \frac{m_N}{b_N}$$

Table 3.13 Repeat purchasing

	Incidence of repeat buyers		Buying frequency per repeat buyer		Buying frequency of new buyers	
Supplier	**O**	T	**O**	T	**O**	T
MEDTRONIC	**57.1%**	56.5%	**1.8**	2.2	**1.7**	1.3
BOSTON	**28.6%**	57.7%	**2.0**	2.3	**1.6**	1.3
ABBOTT	**75.0%**	54.2%	**1.7**	2.2	**2.0**	1.3
OTHER	**50.0%**	40.4%	**2.0**	1.6	**1.0**	1.2
Average Supplier	**52.7%**	52.2%	**1.9**	2.1	**1.6**	1.3
Correlation, r	-0.08		-0.43		0.91	
Mean Absolute Deviation	15.0%		0.4		0.4	

The instance of repeat buying by light and heavy buyers can also be calculated from the NBD. The proportion of buyers who buy at all in the second period, conditional on having made *r* purchases in the preceding period ($p_{i|r}$) is given by

$$p_{i|r} = 1 - \left(1 + \frac{m/k}{1 + m/k}\right)^{-(k+r)}$$

Note that this is not expressed as a proportion of the total population but as a proportion of the number of buyers who made *r* purchases in Period 1.

The average purchase frequency per repeat buyer, conditional on having made *r* purchases in the preceding period ($w_{i|r}$) is given by

$$m_{i|r} = \left(\frac{m/k}{1 + m/k}\right) \times (k + r)$$

$$w_{i|r} = \frac{m_{i|r}}{p_{i|r}}$$

These measures can be calculated for $r = 0, 1, 2, \ldots$. Of course for $r = 0$, this is the special case of new buyers. It will also be necessary to calculate the repeat buying estimates for buyers who purchased more than r times in the preceding period. This is achieved by calculating the required measures up to r and then subtracting from the total number of buyers and the total number of purchases predicted in the second period.

The repeat buying proportions ($p_{i|r}$) are expressed on a "per informant" basis to avoid explicitly introducing the sample size. The proportion of informants not buying in the first period is p_0 or $(1 - b)$. A proportion of these Period 1 non-buyers ($p_{i|0}$) purchase in the second period, such that the percentage of the population (i.e. all informants) who buy in the second period, having not bought in the first, is given by,

$$b_{i|0} = p_0 \times p_{i|0}$$

The purchase rate of these new buyers is $w_{i|0}$, such that the total number of purchases per informant made by these buyers is $w_{i|0} \times b_{i|0}$.

In the same way the proportion of informants buying r times in the first period (p_r) can be determined from the NBD distribution. Of this proportion, $p_{i|r}$, purchase in the second period such that the percentage of the population (i.e. all informants) who buy in the second period, having bought r times in the first, is given by,

$$b_{i|r} = p_r \times p_{i|r}$$

The purchase rate of these new buyers is $w_{i|r}$, such that the total number of purchases per informant made by these buyers is $w_{i|r} \times b_{i|r}$.

The residual proportion of buyers who purchase in the second period, having purchased more than *r* times in the first period is given by,

$$b_{i|>r} = b - \sum_{r=0}^{r} b_{i|r}$$

and the residual number of purchases made by these buyers is given by,

$$(w \times b) - \sum_{r=0}^{r} (w_{i|r} \times b_{i|r})$$

The preceding expressions assume stationarity such that *b* and *w*, the total number of buyers (on a per informant basis) and the total number of purchases that they make, are the same in the first and second period.

The proportion of repeat buyers who also purchased more than *r* times in the first period can then be expressed as a proportion of the buyers who bought more than *r* times,

$$p_{i|>r} = \frac{b_{i|>r}}{1 - \sum_{r=0}^{r} p_r}$$

Expressing the purchase frequency on a per buyer (rather than per informant) basis gives the Period 2 purchase frequency for buyers who made more than *r* purchases in the first period.

$$w_{i|r} = \frac{(w \times b) - \sum_{r=0}^{r} (w_{i|r} \times b_{i|r})}{b_{i|>r}} \times 100$$

3.4.5.1.5 Share of Category Requirements

The total category usage made by buyers of a particular supplier (w_P) can be calculated from the Dirichlet model.

$$w_P = \left(1(P_1 - p_{0|1}) + 2(P_2 - p_{0|2}) + \ldots + (n'+1)(P_{n'+1} - p_{o|n'+1})\right) / b$$

The share of category requirements can then be calculated from w/w_P, where w is the purchase frequency for the particular supplier.

Table 3.14 Share of category requirements (2 week)

	O	T
MEDTRONIC	**39.4%**	43.6%
BOSTON	**41.7%**	42.4%
ABBOTT	**28.5%**	34.2%
OTHER	**87.5%**	24.1%
Average Supplier	**49.3%**	36.1%
Correlation, r	-0.77	
Mean Absolute Deviation	18.5%	

3.4.5.1.6 Proportion of sole buyers

The proportion of the population who only buy from a single supplier (b_S) in the analysis period is given by,

$$b_S = p_{1|1} + p_{2|2} + \ldots + p_{(r'+1)|(n'+1)}$$

This can be expressed as a proportion of all buyers of the particular supplier by dividing b_S by the penetration for the supplier, b.

Table 3.15 Proportion of buyers of a particular supplier who only buy from that supplier

	O	T
MEDTRONIC	**22.6%**	28.3%
BOSTON	**28.6%**	27.5%
ABBOTT	**0.0%**	22.7%
OTHER	**75.0%**	17.1%
Average Supplier	**31.5%**	23.9%
Correlation, r	-0.63	
Mean Absolute Deviation	21.8%	

The average number of purchases made by sole buyers in the period is,

$$w_S = \left(p_{1|1} + 2p_{2|2} + \ldots + (n'+1)p_{(r'+1)(n'+1)}\right) / b_S$$

Table 3.16 Average purchase frequency of sole buyers

	O	T
MEDTRONIC	**1.3**	1.3
BOSTON	**0.5**	1.2
ABBOTT	**0.0**	1.2
OTHER	**1.2**	1.1
Average Supplier	**0.7**	1.2
Correlation, r	0.06	
Mean Absolute Deviation	0.5	

3.4.5.1.7 Duplication of purchase

The proportion of the population who buy from two suppliers (X and Y) is estimated by calculating their separate and combined penetrations. Buyers of X and Y can either buy X only, Y only or X and Y together. The proportion buying X and Y together is given by,

$$b_{XY} = b_X + b_Y - b_{(X+Y)}$$

$b_{(X+Y)}$ is determined by forming a composite supplier (X+Y), and revising the matrix of Dirichlet proportions as described above to give the composite penetration. This data can be presented in a duplication table as shown in Figure 3.3.

		Suppliers		
		X	*Y*	*Z*
	X		$b_{X\|Y}$	$b_{X\|Z}$
Suppliers	*Y*	$b_{Y\|X}$		$b_{Y\|Z}$
	Z	$b_{Z\|X}$	$b_{Z\|Y}$	

Figure 3.3 Matrix of Duplication proportions

Using the pilot data, the two week duplication table is as shown in Table 3.17 where the values represent the proportion of the overall population who buy from a pair of suppliers. The values on the diagonal are simply the two week penetrations for the particular supplier (see Table 3.3).

Table 3.17 Percentage of overall population buying from a pair of suppliers

	Who also purchase from:			
First Purchase	Second Purchase			
Buyers who purchase from:	MEDTRONIC	BOSTON	ABBOTT	OTHERS
MEDTRONIC	16.3	8.5	7	4
BOSTON	8.5	15	6.9	4
ABBOTT	7	6.9	11.3	3.3
OTHERS	4	4	3.3	6.3

Conditional proportions can also be calculated, for example the proportion of buyers of supplier Y that also buy X and vice versa.

$$b_{X|Y} = \frac{b_{XY}}{b_Y},\ b_{Y|X} = \frac{b_{XY}}{b_X}$$

Table 3.18 Percentage of buyers of one supplier who also buy from another

	Who also purchase from:			
First Purchase	Second Purchase			
Buyers who purchase from:	MEDTRONIC	BOSTON	ABBOTT	OTHERS
MEDTRONIC		54.8	45.4	26
BOSTON	56.3		45.7	26.2
ABBOTT	58.6	57.4		27.7
OTHERS	62.4	61.3	51.7	
Average observed duplication	59.1	59.35	48.7	26.95

The Duplication Coefficient, D_{XY} can also be calculated.

$$D_{XY} = \frac{b_{XY}}{b_X \times b_Y}$$

According to the Duplication of Purchase Law the duplication coefficients are expected to be the same for each pair of suppliers in the category.

Table 3.19 Duplication of Purchase Coefficients

	Who also purchase from:			
First Purchase	Second Purchase			
Buyers who purchase from:	MEDTRONIC	BOSTON	ABBOTT	OTHERS
MEDTRONIC		3.48	3.80	3.90
BOSTON	3.48		4.07	4.23
ABBOTT	3.80	4.07		4.64
OTHERS	3.90	4.23	4.64	
Average duplication coefficient	3.72	3.93	4.17	4.25

3.4.5.2 Testing the Model

Having derived the set of supplier performance measures, it is necessary to test whether the model holds i.e. are the predicted values are indeed a good fit to the observed values.

The purpose of the goodness of fit test is not just to compare the distribution of measures from the data with the distribution predicted by the model to accept or reject the hypothesis, i.e. that the observed data can be described by the NBD-Dirichlet model. Just because a fit has been obtained at some confidence level does not mean that the model is correct (Schunn & Wallach, 2001). There are other models, other data sets that could lead to equally good fits. However taken in the context of the NBD-Dirichlet empirical generalisation, where validation of the model is through replication to new situations, a good fit signifies a further replication and adds to the heuristic power of the model. This is the application of Sophisticated Methodological Falsification (Leong, 1985) where each

experiment or test of the model in itself does not lead to the universal acceptance or rejection of the model but does add to the body of knowledge that constitutes the "positive heuristic" of the model. As Ehrenberg (1988, p.23) notes, "the important point is not so much whether the discrepancies are real (or merely sampling errors) but that the same theoretical formula accounts for the greater part of the observed variation and that the residual deviations are relatively small and more or less unbiased."

The treatment of goodness of fit in replicated studies has been the subject of much comment (Ehrenberg & Bound, 1993; Lindsay & Ehrenberg, 1993; Ehrenberg, 1994; Barwise, 1995), in particular the distinction between the best fit correlation for a single set of data and what has been called "significant sameness" (Barwise, 1995), "stochastic sameness" (Ehrenberg & Bound, 1993) or a "generally good fit" (Uncles et al, 1995) across many sets of data. The relationship between the expected and observed behaviours "should hold within much the same limits of scatter as before" (Ehrenberg & Bound, 1993) and without any systematic bias (Ehrenberg, 1994).

Visual displays are useful for a rough estimate of degree of fit and for indicating where the fits are problematic, including the identification of any systemic biases or market partitioning through what Ehrenberg (1988) has referred to as "eyeballing". In the current research, tabulation of the data is the first of these techniques. A variety of conventions assist the researcher to estimate degree of fit. These include:

(a) Tabulate supplier data in descending order of market share. This allows observation of the expected trends (market shares and

penetrations decrease across the suppliers while purchase frequencies are relatively constant). The Double Jeopardy observation, i.e. that smaller brands suffer from lower purchase frequencies can also be easily noticed in this kind of tabulation.

(b) Tabulated data should be rounded to enable easy visual comparison of measures. It is easier to compare 17.9% and 18.2% than 17.8765% and 18.2477%

(c) Tables should present the observed data first with the predicted (theoretical) data alongside it. Observed data should be in bold.

Graphical representations can also be used, for example for the observed and theoretical frequency distributions. These may be line graphs or side by side bar charts. A useful convention is to present observed data with closed icons and solid lines; theoretical values are represented by open icons and dotted lines. The charts will show any systemic deviations and whether the direction of any trends is adequately captured by the model.

A variety of numerical measures to assess goodness of fit have been used in the Dirichlet and related literature as shown in Table 3.20. The most commonly used measures are the individual deviations, Mean Absolute Deviation, the Mean Absolute Percentage Error and the correlation coefficient. This research uses the same set of measures. As there is a range of performance measures predicted by the Dirichlet model, from frequency distributions to discrete supplier performance measures, no single value for the average deviation can be used as a benchmark. An analysis of the studies cited above has shown that the Mean Absolute Deviation is typically about 10% of the mean of the particular

performance measure. The range of individual deviations is typically ±50% of the expected values, with more than half (>70%) of deviations within ±10% of the theoretical predictions. The correlation coefficient, *r* gives a measure of the strength of the relationship between observed and theoretical data, with a benchmark correlation between the expected and actual values of the order of 0.9 (Ehrenberg, 1994; Uncles et al, 1995).

Table 3.20 Selection of Goodness of Fit measures used in Dirichlet studies

Study	***Goodness of fit measures***
(Ehrenberg, 1988)	*Mean Absolute Deviation*
(Bowman & Lele-Pingle, 1997)	r^2, *Mean Square Deviation*
(Ehrenberg, 1959)	*Root Mean Square Deviation*
(Pickford & Goodhardt, 2000)	*Mean Absolute Deviation*
(Stern & Hammond, 2004)	r, *Mean Absolute Deviation*
(Uncles et al, 1995)	r
(Li et al, 2009)	*Deviation*
(Kahn et al, 1988)	*Deviation*
(Bhattacharya, 1997)	r^2, *Deviation*
(Kearns & Lewis, 2000)	*Mean Absolute Deviation*
(Leckenby & Kishi, 1984)	*Percentage Error*
(Schmittlein & Peterson, 1994)	*Mean Square Deviation*
(Sharp et al, 2002)	*Deviation*
(Sharp & Driesener, 2000)	*Mean Absolute Deviation*
(Uncles & Kwok, 2003)	*Mean Absolute Deviation*
(Uncles & Ehrenberg, 1990)	*Deviation*
(Wright et al, 2002)	*r, Mean Absolute Deviation, Mean Absolute Percentage Error*
(Lam & Mizerski, 2009)	*r,* r^2, *Mean Absolute Deviation*

Further, an understanding of the discrepancies between the observed and predicted measures, and any areas of systematic deviation, highlights

suggestions for further research. These could include more systematic research into the deviations themselves (to see whether they can themselves be replicated), the validity of the model assumptions, sensitivity to changes in the model parameters or specific issues related to the data, for example non-stationarity or partitioning.

3.5 Qualitative Analysis

The coronary stent category has been chosen in part because it has been the subject of recent purchasing activity and the longitudinal analysis includes a period of non-stationary behaviour. The NBD-Dirichlet model may predict with some accuracy the buying behaviours before and after any purchasing interventions but it does not provide any insights into the actual interventions taken. In order to provide background information to aid interpretation of the observed behaviours, exploratory interviews are conducted after the analysis of the data.

Qualitative data is collected through semi-structured interviews with key collaborative procurement hub purchasing personnel involved in the cardiac stent category purchasing process in order to provide feedback on the findings of the modelling and to explore the context and background of the purchasing interventions (Miles & Huberman, 1994; Silverman, 1997).

Organisational change, both imposed by government and internally driven change, means that the individuals involved in the original interventions in 2006 – 2008 are either no longer in post or not available for interview. Two senior procurement executives are interviewed, including the current Deputy Director of Procurement for the Collaborative Purchasing Hub. Although not involved in

the original cardiac stent project, the Deputy Director is now responsible for the implementation of the framework agreements negotiated during the project. The second interviewee was formerly a procurement executive in the CPH and was directly responsible for the cardiac stent project in 2007 – 2008. She is currently the Procurement Director for a large acute hospital trust that is a member of the CPH and a major purchaser of cardiac stents.

The interviews last approximately one hour each and are conducted either face-to-face or by telephone. It is recognised that the interviews involve recollections of events that happened over three years ago and that interviewees may want to construct a story that appears logical and consistent (Myers & Newman, 2007). To avoid contributing to this constructed knowledge, the findings of the research are not shared with the interviewees before the interviews. The interviews are semi-structured and are taped and transcribed before analysis to explore the background, context and implementation of the cardiac stent project. The interview guide and an extract from the transcript are included in Appendix C.

3.6 Summary

This chapter presents the epistemological assumptions that underpin the Empirical then Theoretical (EtT) approach advocated by Ehrenberg (1994) and the application of the NBD-Dirichlet in buyer behaviour research. The EtT approach is located within the Lakatosian concept of sophisticated methodological falsification within a research programme (Leong, 1985).

The design of the research study is also discussed, emphasising the importance of this replication to extend the generalisability of the NBD-Dirichlet model and its practical applicability, in this case into a new discipline as well as a new

market. The research methodology is presented, including data collection, operationalisation of the model and testing of the model. Worked examples using data from a pilot study are used to demonstrate the calculation methods. The pilot study is also used to identify a suitable category for analysis and to confirm the form and availability of the information required for the longitudinal study. Two stent categories will be analysed as separate cases, one where there has been no purchasing management intervention (ureteral stents) and one where there has been an intervention (coronary stents).

Data is collected from a single hospital trust and a Collaborative Procurement Hub (CPH) within the English National Health Service (NHS). The collaborative public procurement environment in the NHS is a complex context that will be discussed briefly in the next chapter.

4 Procurement in the National Health Service

4.1 Introduction

The previous chapter has introduced pilot data from a single NHS hospital trust in which coronary stents have been selected as the category for study and the data requirements and availability have been confirmed. The main body of the research is a longitudinal study into stent purchases in a collaborative procurement hub in the English NHS.

This chapter presents a brief overview of the procurement arrangements within the NHS and highlights some of the tensions that exist between the design and specification of clinical solutions and their sourcing. It explains why stent purchases within the NHS is a suitable case to analyse in the context of the research objectives to investigate the behaviour of purchasers in a collaborative procurement environment, in particular to seek to identify whether the behaviours followed any regular pattern, if the observed patterns could be described and predicted using a robust model of buyer behaviour, the NBD-Dirichlet, and whether such modelling can be used to inform management decision making in a collaborative purchasing context.

In particular, procurement in the NHS is a complex and challenging test for the Dirichlet model, and as such represents a differentiated replication (Lindsay & Ehrenberg, 1993); an extension into very different market conditions. As well as extending the application of the Dirichlet model from a broadly consumer marketing environment to a purchasing and supply chain context, the NHS case includes a complex and highly regulated collaborative public procurement

structure with decision makers at multiple levels, from clinicians to policy makers. The limitations of the NHS as a research subject are also discussed, including the availability and accuracy of data from fragmented computer systems and the small samples that result from a limited purchasing population.

4.2 NHS Structure

This large and complex organisation, the world's largest publicly funded health service (NHS, 2009) is committed to "bringing the highest levels of human knowledge and skill to save lives and improve health" (Department of Health, 2010b; Department of Health, 2010a) (Department of Health, 2010a; Department of Health, 2010b). Third party expenditure on goods and services used in the NHS is some £20 billion per year (Department of Health, 2010a), about 20% of the total NHS annual budget of over £100 billion (NHS, 2009).

The structure of the NHS can change rapidly with changes in the political environment such as devolution or a change in government. As a result, any description of the NHS or its purchasing organisation may often become out of date. The current (June 2009) structure of the NHS in England is shown in a simplified form Figure 4.1 (McCay & Jonas, 2009).

This reflects the most recent significant restructuring in the English NHS. In July 2006 the number of Strategic Health Authorities (SHA) was reduced from the twenty eight set up in 2002 to ten. There are now 152 Primary Care Trusts (PCT), compared to the 304 PCTs that replaced the NHS Community Trusts and Health Authorities in 2002. The Department of Health controls the ten SHAs directly, which themselves supervise all the non-foundation NHS Trusts in their

area (Harland et al, 2007; NHS, 2009). Each SHA covers a population of between 2.5 – 7.5 million people (Galloway, 2009).

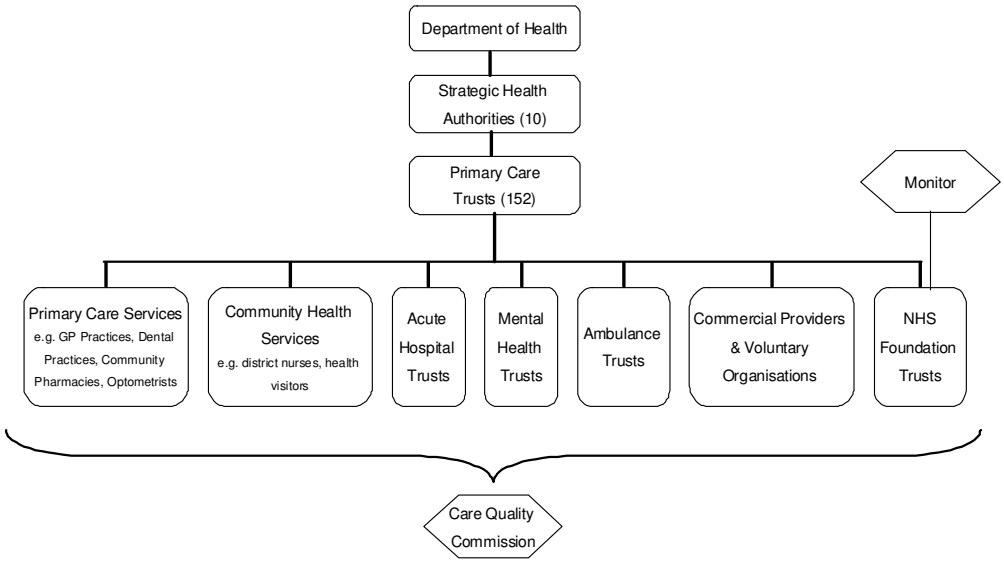

Figure 4.1 Structure of English National Health Service

4.2.1 Primary Care Trusts

Primary Care Trusts (PCTs) are the main commissioners of healthcare in the NHS, controlling 80% of the NHS budget. Funding for hospitals (NHS Trusts, Foundation Trusts) and contracts with non - NHS providers now come primarily from PCTs. Each PCT serves a population of approximately 150,000 – 300,000 people (Galloway, 2009).

Primary care is usually the first point of contact to the NHS – the people seen when one first has a health problem. These include GPs, optometrists or NHS Direct (Harland et al, 2007). The PCT is responsible for ensuring that there are enough health and social care services for people within their area and that these services are accessible. It must also make sure that all other health services are provided, including GPs, dentists, opticians, mental health services, NHS walk-

in centres, the NHS Direct telephone service, patient transport (including accident and emergency), screening and pharmacies. They are also responsible for getting health and social care systems working together for the benefit of patients (NHS, 2009)

Five of the 152 PCTs are currently Care Trusts (NHS, 2009), working in both health and social care to deliver both services together. Care trusts are set up when the NHS and local authorities agree to work in tandem, usually when it is felt that a closer relationship between health and social care is needed or would benefit local care services. In areas where Care Trusts have not been established, Primary Care Trusts and Social Services work as independent agencies (NHS, 2009; Galloway, 2009).

4.2.2 NHS Trusts

NHS hospital, mental health and ambulance services are generally provided by trusts. They form part of the secondary care sector and are usually the second stage of contact with the NHS, providing healthcare services that have been commissioned by PCTs and practice-based commissioners (Galloway, 2009; Department of Health, 2009a).

Acute trusts manage hospitals to ensure that they provide high-quality healthcare and that they spend their money efficiently. Some acute trusts are regional or national centres for more specialised care while others are attached to universities and help to train health professionals. There are 168 acute trusts in England (NHS 2009).

There are 12 ambulance services in England, providing emergency access to healthcare. The NHS is also responsible for providing transport to get many patients to hospital for treatment. In many areas it is the ambulance trust that provides this service (NHS, 2009).

Mental health trusts provide health and social care services for people with mental health problems. There are 73 mental health trusts in England. Mental health services may be provided through your GP or other primary care services with more specialist care normally provided by mental health trusts or local council social services departments (NHS, 2009).

4.2.3 Foundation Trusts

Since 2004, trusts have been able to apply to change their status to NHS Foundation Trusts. As of 4th December 2009 there were 122 NHS Foundation Trusts in England (NHS, 2009). The Department of Health intends for all NHS Trusts to become NHS Foundation Trusts over time (Department of Health, 2009a).

NHS foundation trusts provide the same kind of services as any other hospital, mental health or ambulance trust but are accountable in a different way and have greater freedoms although they remain within the NHS and its performance inspection system. NHS foundation trusts are not overseen by strategic health authorities or the Department of Health but are instead regulated by an independent body called Monitor.

4.2.4 Regulation

Since April 2009, the safety and quality regulator for all health services has been the Care Quality Commission, replacing the Healthcare Commission, Mental Health Act Commission, and the Commission for Social Care Inspection. The Care Quality Commission has the power to inspect all registered healthcare providers, to suspend services, impose fines, prosecute or deregister organisations if it has evidence that suggests a serious problem that may be putting patients at risk.

Unlike NHS trusts, which are overseen by strategic health authorities, NHS foundation trusts are regulated by Monitor, an independent regulator. NHS foundation trusts are assessed by the Care Quality Commission in the same way as other hospitals.

4.3 Purchasing and Supply in the NHS

Procurement has long been at the forefront of efficiency drives within the National Health Service (NHS). As the Department of Health observes in their paper introducing a new commercial operating model for the NHS and Department of Health, "Necessity – not nicety",

> "*Looking at the NHS as a whole, the key benefit will be to put the system in a strong position to realise demanding procurement efficiency expectations and to maximise the NHS's spending power for the benefit of patient care*".
>
> (Department of Health, 2009b, p12)

4.3.1 Structure

Purchasing and supply in the English NHS has been the subject of a longitudinal collaborative action research programme with the Centre for Research in Strategic Purchasing and Supply (CRiSPS) since 1995 (Walker et al, 2008). Consequently there is a wide range of historical and case study literature describing NHS procurement and how it has evolved over the past fifteen years.

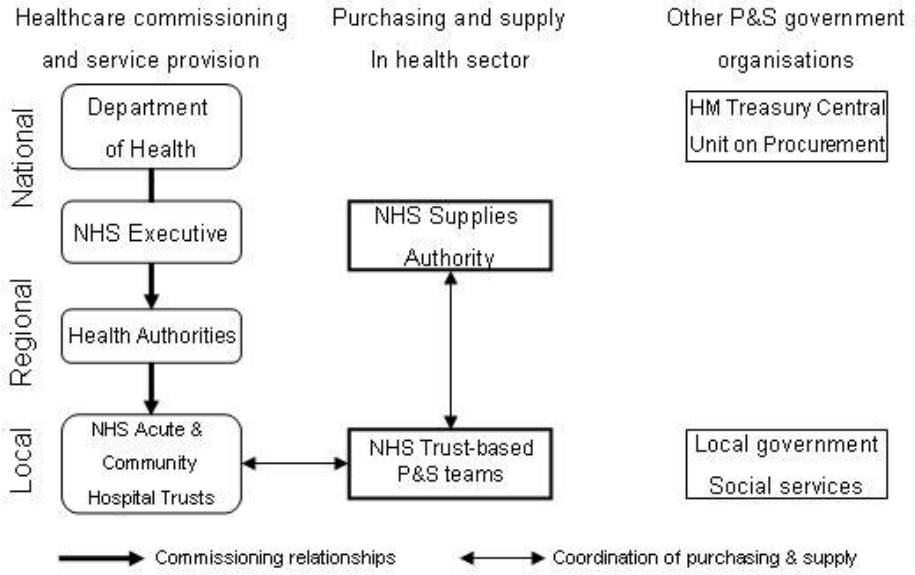

Figure 4.2 Structure of NHS Purchasing & Supply 1997-1998 (Harland et al, 2007)

As been noted already, procurement has often been a driver for efficiency savings within the NHS. The NHS Supplies Authority was set up in 1991 to address inefficiencies by coordinating spending and improving supply management (Figure 4.2). Initially set up on a regional basis, NHS Supplies developed into a national structure in 1995, providing a national logistics service, a contracting service to establish national framework agreements and provide purchasing expertise to individual trusts and a customer service function to manage trust-based purchasing and supply functions (Harland et al, 2007).

Trusts were under no obligation to use the services of NHS Supplies which had no central funding and covered its costs through consultancy fees, product handling fees and annual fees from the trusts. Several trusts established independent purchasing and supply departments creating wide variability in supply management effectiveness across the NHS (Harland et al, 2007).

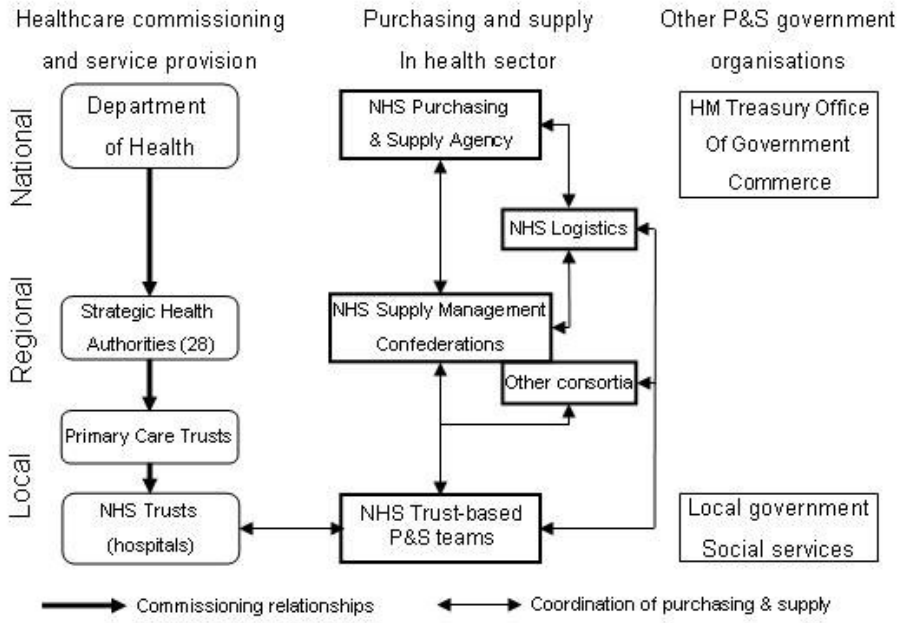

Figure 4.3 Structure of NHS Purchasing & Supply 2002-2003 (Harland et al, 2007)

The NHS Purchasing and Supply Agency (NHS PASA) was established in April 2000 as part of a restructuring that replaced NHS Supplies with two organisations - NHS Logistics (a service since outsourced to DHL) and NHS PASA (Figures 4.3 and 4.4). Compared to the operational role of NHS Supplies, NHS PASA had a remit to develop policy and strategy on behalf of the health service and to ensure that the NHS in England made the most effective use of its resources by getting the best possible value for money when purchasing goods and services. Centrally funded, it was a purchasing centre of excellence for the NHS as well as continuing to provide a contracting service for national

framework agreements. Its prime target was to release money that could be better spent on patient care by achieving purchasing savings and improving supply performance across the NHS (Harland et al, 2007; Department of Health, 2009c).

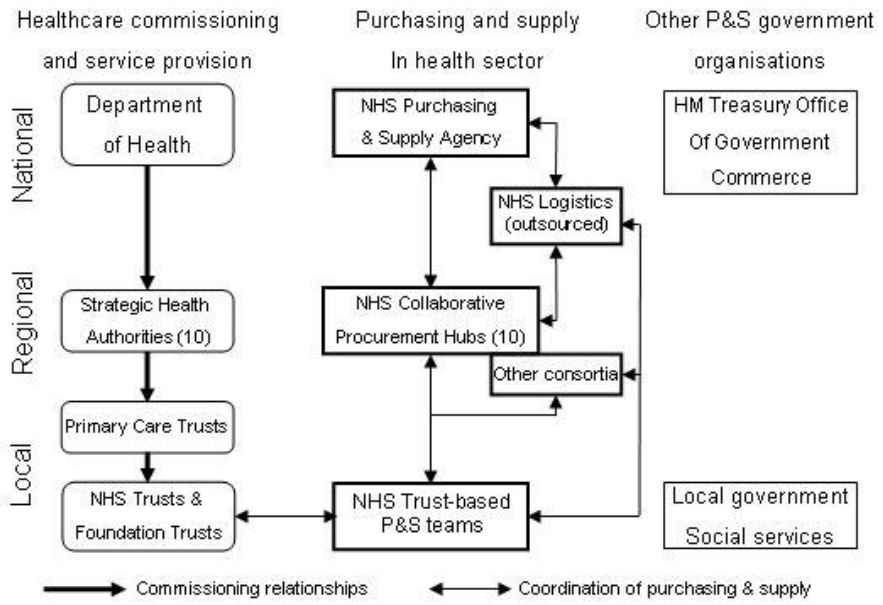

Figure 4.4 Structure of NHS Purchasing & Supply 2007-2009

In May 2009 the Department of Health launched a new Commercial Operating Model. Procurement of goods and services was perceived to be piecemeal and sub-optimal. Under this new model the NHS PASA function was closed in October 2009 with its functions transferring to the Office of Government Commerce Buying Solutions (OGCbs) for non-clinical supplies, to the NHS Logistics Authority to form NHS Supply Chain and to the NHS Commercial Medicines Unit (CMU) within the Department of Health (Department of Health, 2009b). The proposed new structure is shown in Figure 4.5.

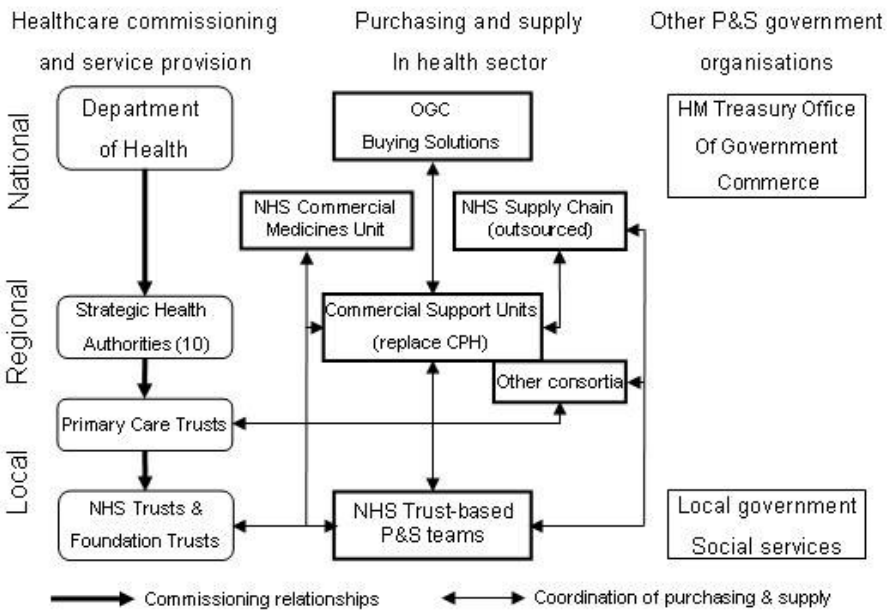

Figure 4.5 Structure of NHS Purchasing & Supply 2010-

4.3.2 Collaborative Purchasing in the NHS

Group or consortia purchasing has been identified as a way to improve effectiveness in public sector supply management effectiveness (Cleverley & Nutt, 1984; Nollet & Beaulieu, 2003; Phillips et al, 2008; Loader, 2010). Purchasing consortia can be formed between national and local decision making, often on a regional or cross-government basis (Harland et al, 2005). While the benefits of aggregating volume to increase leverage with suppliers, to deliver economies of scale and to reduce transaction costs are well documented (Nollet & Beaulieu, 2003), several authors have noted potential negative effects such as supplier concentration and a consequent reduction in competition and disenfranchisement of smaller suppliers through raised entry barriers (Harland et al, 2005; Loader, 2010). It has been recognised that "good value can only occur if there is a sufficient choice of appropriate suppliers available" (Loader, 2010,

p.46) and that public procurement may have a role to play in market creation (Caldwell et al, 2005; Walker et al, 2006).

Procurement in the NHS has been and continues to be described as fragmented and piecemeal (Knight et al, 2003; Department of Health, 2009b). A number of national initiatives have attempted to address the inefficiencies arising from this fragmentation, including the establishment of NHS Supplies in 1991, the restructuring of NHS Supplies into NHS PASA and NHS Logistics in 2000, the establishment of a new Commercial Directorate within the Department of Health in 2003 and the most recent changes to NHS PASA and NHS Logistics to consolidate procurement functions into OGCbs, NHS Supply Chain and the CMU in the Department of Health in 2009 (Harland et al, 2007; Department of Health, 2009b). A simplified view of the evolving structure of purchasing and supply in the NHS is shown in Figures 4.2 to 4.5.

Informal arrangements for coordination of purchasing and supply at a level between the local and the national have also been a feature of the NHS on regional or functional bases (Harland et al, 2007). NHS PASA also introduced more formal arrangements with the establishment of six "Pilot Confederations", purchasing and supply organisations covering all the trusts within a SHA. By 2005, 95 per cent of trusts belonged to a confederation (Harland et al, 2007). The Commercial Directorate in the Department of Health also introduced a Supply Chain Excellence Programme (SCEP) in 2004. With the aim of improving supply efficiency, one of the projects under SCEP was the establishment of Collaborative Procurement Hubs (CPH) to deliver consistency in regional purchasing. These CPHs would have a remit to deliver £270 million

savings by 2007, to improve support for clinicians involved in purchasing and to encourage innovation. Three pathfinder CPHs were established to test and refine the CPH model, starting formal operation in April 2005. There are now ten CPHs covering the majority of trusts (Phillips et al, 2008). Whereas confederations were voluntary and virtual organisations, the CPHs are separate organisations, owned by all the member trusts with dedicated resources (Harland et al, 2007).

The core activities carried out by the hubs on behalf of their members include category procurement to provide a collaborative and integrated approach to procurement and delivering price reductions through aggregation. Key to this is a requirement to develop and implement common data collection methodologies in order to facilitate aggregation, to monitor savings and to profile purchasing behaviours to identify patterns of significant and outlying spend. These activities are complicated by the reluctance of trusts to collect data, seeing this as onerous. As a result, poor quality data continues to be an issue (Anonymous, 2009a).

The CPHs are now undergoing a further period of change with the establishment of regional Commercial Support Units (CSUs) which will replace the CPHs but will support commissioners of healthcare (PCTs and practice-based commissioners) as well as providers (NHS Trusts) (Department of Health, 2009b; Department of Health, 2010a).

4.3.3 Procurement Decision-Making in the NHS

Sourcing decisions in the NHS are mostly made by budget holders at trust level. Decisions may be constrained by framework agreements (national or regional)

but clinicians in particular can be influenced directly by suppliers and have significant influence in sourcing decisions (Harland et al, 2007; Phillips et al, 2008). Decisions concerning products and services ordered centrally within a trust (e.g. food) and capital equipment are typically taken by a group representing trust stakeholders, facilities managers or in some cases contractors to whom services may have been outsourced.

An additional factor impacting sourcing decisions in the NHS is the objective to improve clinical outcomes. The National Institute of Clinical Excellence (NICE) and has been established to evaluate health technologies and set policy concerning their use across the NHS. In addition, the Centre for Evidence-based Purchasing (CEP) provides objective evidence to support adoption of innovative products and procedures in healthcare and to inform procurement decisions (Harland et al, 2007; Phillips et al, 2008).

4.3.4 Constraints Facing NHS Procurement

There are a range of external and internal factors that add to the complexity of NHS procurement. External factors include changes in the political macro-environment. Examples in recent years include the move from compulsory competitive tendering (CCT) to voluntary competitive tendering (VCT) following the change of government in 1997 and changes in purchasing objectives from cost savings to value for money, including issues such as sustainability and improved patient outcomes (Harland et al, 2007; Phillips et al, 2008; Walker et al, 2008). The Department of Health explicitly sees procurement as a means to contribute to the "social, economic and environmental aspects of sustainability" (Department of Health, 2010a, p.11).

Ministerial responses to adverse media or arising events may also trigger changes in supply strategy (Walker et al, 2008). A further external factor concerns technological development and the adoption of new technologies as trusts work towards improved clinical outcomes (Harland et al, 2007; Walker et al, 2008). While the trend towards evidence-based medicine provides objective support for purchasing decision-making, the localisation of purchasing can militate against uptake of innovative technologies.

Individual trusts remain accountable for their budgets and delivering targeted procurement savings. Policies to return power and control over budgets to the "front line" create tensions between trusts and the aggregators of demand, whether regional or national (Harland et al, 2007). In addition, clinicians enjoy considerable discretion over sourcing decisions for pharmaceuticals, medical equipment and consumables, leaving them open to supplier opportunism and lock-in to preferred suppliers. This can make supplier rationalisation difficult to achieve (Cox et al, 2005).

Excessive local autonomy can result in "shadow procurement" organisations, non-compliance or maverick buying i.e. buying outside the centrally negotiated framework agreements (Harland et al, 2007; Phillips et al, 2008). It has been noted that control of off-process procurement is a key element in improving purchasing performance (Croom & Brandon-Jones, 2007).

However, fragmented information systems and inconsistencies in supplier or product coding mean that there is limited direct visibility of what is bought and by whom (Bakker et al, 2006b; Harland et al, 2007). As well as being unable to monitor compliance with framework agreements and establish accurate

consumption histories or forecasts, this lack of information means that market structures cannot be assessed effectively to ensure competitiveness and balance (i.e. neither too many nor too few suppliers) (Caldwell et al, 2005; Walker et al, 2006).

4.4 Stent Purchases in the NHS

Coronary stents are small scaffold-like structures that are inserted into arteries to stop them from narrowing and becoming blocked (see Figure 4.6). In coronary angioplasty a catheter is inserted into the patient's leg or wrist and fed up through a main artery until it reaches the blockage. A small balloon attached to the end of the catheter is inflated to clear the blockage and expand the stent. Two broad categories of stent are available – the Bare Metal Stent (BMS) and the Drug Eluting Stent (DES) which is coated to deliver controlled dose of a therapeutic agent to the injured artery over a prolonged period, preventing it from becoming blocked again.

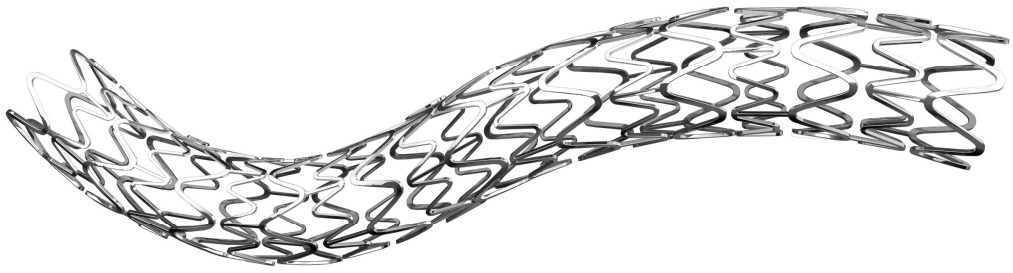

Figure 4.6 TAXUS® Express²™ Atom™ Paclitaxel-Eluting Coronary Stent System

The stent market is dominated by four major suppliers, Boston Scientific, Medtronic, Abbott and Johnson & Johnson. A number of other suppliers also

serve the market, including B Braun, Biotronik, Cook, Orbus Neich, Pyramed and Terumo (London Procurement Programme, 2010).

The National Institute for Clinical Excellence (NICE) has reviewed the cost-effectiveness of DES which are more expensive than BMS, recommending their use in an appraisal in 2003 before reversing this judgement in their appraisal consultation document on the grounds that DES were not cost effective. In 2007 NICE opted to ban DES on medical grounds. This guidance has since been updated (July 2008) to allow the use of DES in certain circumstances, including specifying a cost differential between DES and BMS of no more than £300 (NICE, 2008; de Belder, 2008). In the UK in 2007 DES cost between £650 and £480 compared to between £100 and £250 for BMS (London Procurement Programme, 2010).

Following the revised NICE guidance, hospital trusts and collaborative procurement hubs have sought to put in place framework agreements to mitigate the expected impact of increased purchases of the more expensive DES. The total annual coronary stent spend for the single hospital trust that provided the pilot data is £1.6 million. During 2008/09 a range of efficiency measures were reported to have delivered savings of £395,455 (Anonymous, 2009b). In the Collaborative Procurement Hub the regional spend on cardiac stents (both bare metal stents and drug eluting stents) was £5 million. Since 2007, the Hub has implemented an improvement project that has realised £1.1 million procurement savings, led to greater standardisation of stents across the region and enhanced existing working relationships in cardiology (Anonymous, 2009a). This project integrated clinician influence and procurement expertise in a consensus

assessment process where product selection was based on practical application and theoretical evidence in order to gain acceptance for the framework agreements and reduce the incidence of off-framework purchasing.

4.5 Summary

This overview of purchasing arrangements in the NHS has shown the complexity of the organisation with multiple influencers including regulatory bodies, national purchasing organisations, regional collaborative hubs, procurement professionals in hospital and other trusts and individual clinicians. This complexity and the historic autonomy of clinicians and hospitals has often resulted in poor compliance to purchasing agreements, so-called "maverick" or off-framework purchasing. With continuing pressure on the procurement function in the NHS to deliver efficiency savings, identifying and overcoming such maverick purchasing is essential to realise the gains available from increased standardisation and vendor rationalisation.

Collaborative purchasing in the NHS is relatively mature and formalised, especially in the regional collaborative procurement hubs. The data used is collected by the hub on a regular basis from purchase order systems. By using secondary data that records observable occurrences (raising a purchase order), the information gathered for the research is not affected by respondent attitudes or expectations. Although the data used in the analysis is generated from a single database (in the collaborative procurement hub), the hub aggregates purchasing data from over sixty individual trusts, overcoming some of the problems associated with fragmented information systems and inconsistent product coding. This aggregation of data reduces some of the issues related to

non-response, common method variance and bias in survey research (Autry & Golicic, 2010).

The coronary stent category is a significant expenditure for the organisations that participated in the research. It has been impacted by changes in regulatory guidance and has been the subject of supply side interventions (negotiated framework agreements) over the period of analysis.

The scope, scale and dynamic nature of this category make it ideal for longitudinal analysis using the NBD-Dirichlet model. The NHS procurement environment with its complexity and multiple influencers is a challenging and highly differentiated replication for the NBD-Dirichlet and as such is a substantial contribution to the literature.

The following chapters present the analysis of patterns of stent purchases in the single trust and in the collaborative purchasing hub. Chapter 5 discusses the pilot data already introduced in Chapter 3. Chapters 6 and 7 consider a longitudinal data set that spans the three years from 2006 to 2008, including the first six months following the implementation of the coronary stent framework agreements. Chapter 6 is a detailed analysis of ureteral stent purchasing patterns, a stent category that has not had any purchasing intervention and is included to allow a comparison with the coronary stent data that is presented in Chapter 7.

5 Pilot Study - Modelling Stent Procurement in a Single NHS Trust

5.1 Introduction

This chapter presents the analysis of pilot data covering purchases of coronary stents by a single NHS hospital trust over a one month period. As noted in the previous chapter, coronary stents have been chosen for analysis because they represent significant expenditure for the trust and are in a procurement category that has seen recent activity to rationalise the supply base and standardise supply. The screening and preparation of the pilot data has been described in Section 3.3 and this chapter will present a description of the data, the fitting of the model and the use of the model to predict purchasing behaviour in subsequent periods.

The analysis shows that even with this relatively short analysis period, the NBD-Dirichlet describes supplier performance measures such as penetration, purchase frequency and share of category requirements with good accuracy. A heavy (high frequency) purchasing segment is identified and shown to purchase from a restricted set of suppliers.

This pilot study identifies coronary stents as a suitable category for analysis and demonstrates that stent purchasing patterns in a single hospital over a limited time period can be modelled using the NBD-Dirichlet. This provides a sound basis for extension of the analysis to the more complex longitudinal analysis of the purchasing patterns in the collaborative purchasing hub.

5.2 Description of the Data

5.2.1 Purchases by Requisitioner

The data covers a 4 week period, stretching from 1 May 2008 to 28 May 2008 inclusive. 14 requisitioners made purchases of coronary stents in the time period, with 6 requisitioners accounting for over 80% of total purchases in the period (Figure 5.1). 5 requisitioners fulfilled all their category requirements with a single supplier in this period although all 5 only made a single purchase, thus having no opportunity to choose another supplier. Of the purchasers who made more than one purchase, in no cases were orders placed predominantly on a single supplier although 5 of the 6 heaviest purchasers only purchased from the three dominant suppliers. The usual expectation would be for the heaviest purchasers to have the greatest opportunity to use the smaller suppliers and for the lightest purchasers to be more likely to use the dominant suppliers, the Natural Monopoly Phenomenon (McPhee, 1963). This is an initial indication of deviation from the typical patterns of a Dirichlet market and may point to some partitioning of the market and a violation of the Dirichlet assumption of independence of supplier choice and purchase incidence. Excess behavioural loyalty for dominant suppliers has been observed previously (Fader & Schmittlein, 1993; Singh et al, 2009) and attributed to segmentation on the basis of different levels of availability or price. In the stent case availability may be constrained by the existence of framework agreements with the main suppliers such that purchases from the smaller suppliers may be off framework purchases.

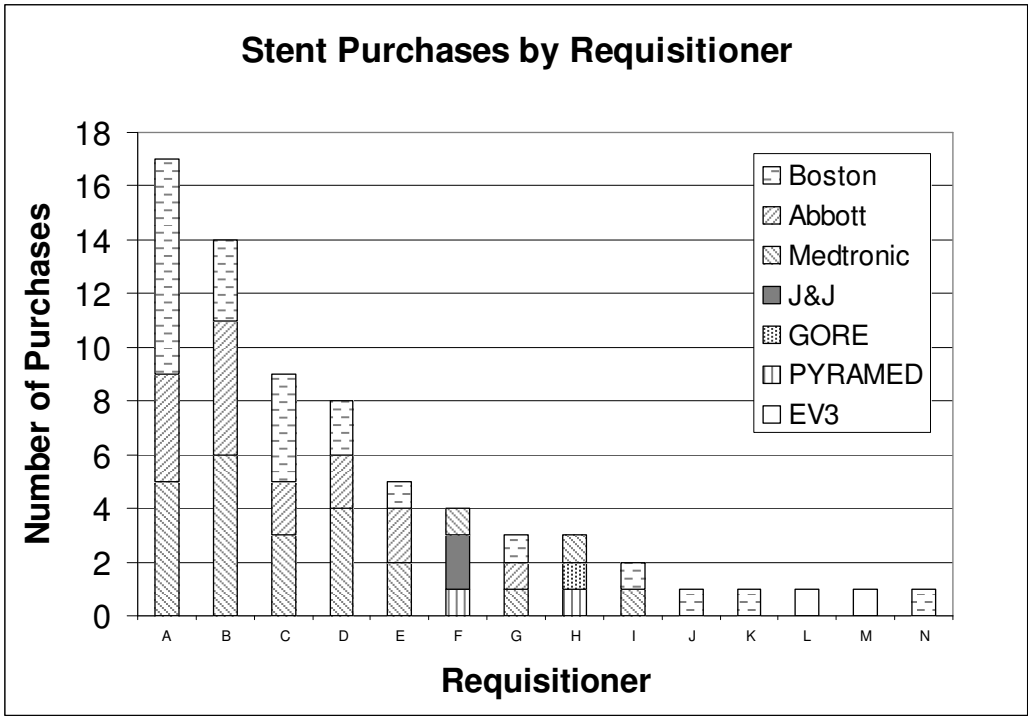

Figure 5.1 Stent purchases by requisitioner

5.2.1.1 Poisson Assumption

One of the underlying distributional assumptions of the NBD-Dirichlet is that purchases by individual buyers follow a Poisson process, such that their long run average purchase frequency is steady. It is not possible to determine a long run average purchase frequency over such a short analysis period but the tabulated weekly purchase frequencies for each buyer (Table 5.1) show that these are fairly steady. The distribution of purchases appears to show an increase in purchases in the middle two weeks of the period. Analysis over a longer period would show if this was a regular pattern. For the purposes of this analysis, an average two week period will be used as the base period in order to smooth out this effect.

Table 5.1 Weekly purchases by requisitioner

Requisitioner	Successive Time Periods (weeks)				Weekly Average
	1	2	3	4	
A	1	10	6		4.3
B	5	3	1	5	3.5
C			3	6	2.3
D	3	3	2		2.0
E		3	2		1.3
F		1	1	2	1.0
G		3			0.8
H		2	1		0.8
I	1		1		0.5
J				1	0.3
K				1	0.3
L		1			0.3
M				1	0.3
N			1		0.3
Total Number of Purchasers	4	8	9	6	6.8
Total Number of Purchases	10	26	18	16	17.5
Overall Purchase Frequency	2.5	3.3	2.0	2.7	2.6

5.2.2 Purchases by Supplier

3 suppliers (Abbott, Boston and Medtronic) account for 63 of the 70 purchase orders, 90% of the total (Table 5.2). To simplify the subsequent analysis, the four suppliers making up the remaining 10% (EV3, J&J, Pyramed, Gore) are consolidated into a single "Others" composite supplier. The table shows that purchases of the three main suppliers are fairly constant through the four weeks, although there is a drop in purchases of Abbott at the end of the period.

Table 5.2 Coronary stent purchases by supplier

	MEDTRONIC	BOSTON	ABBOTT	EV3	J&J	PYRAMED	WL GORE	TOTAL
Week 1	3	3	4					10
Week 2	9	8	5	1	1	1	1	26
Week 3	6	6	5			1		18
Week 4	6	6	2	1	1			16
Total	24	23	16	2	2	2	1	70

Figure 5.2 shows the market shares for the different suppliers through the period. These are relatively steady for two suppliers with the highest share (Medtronic and Boston). The market share for Abbott falls from 40% to 12% over the four weeks and that for the Others rises from zero to 12%. Analysis over a longer time period would show whether this apparent trend was a temporary phenomenon in the particular month, the effect of random variation, a pattern in purchases that was repeated in subsequent months (i.e. purchases of Abbott loaded towards the early part of a month) or a more sustained shift in purchaser preferences.

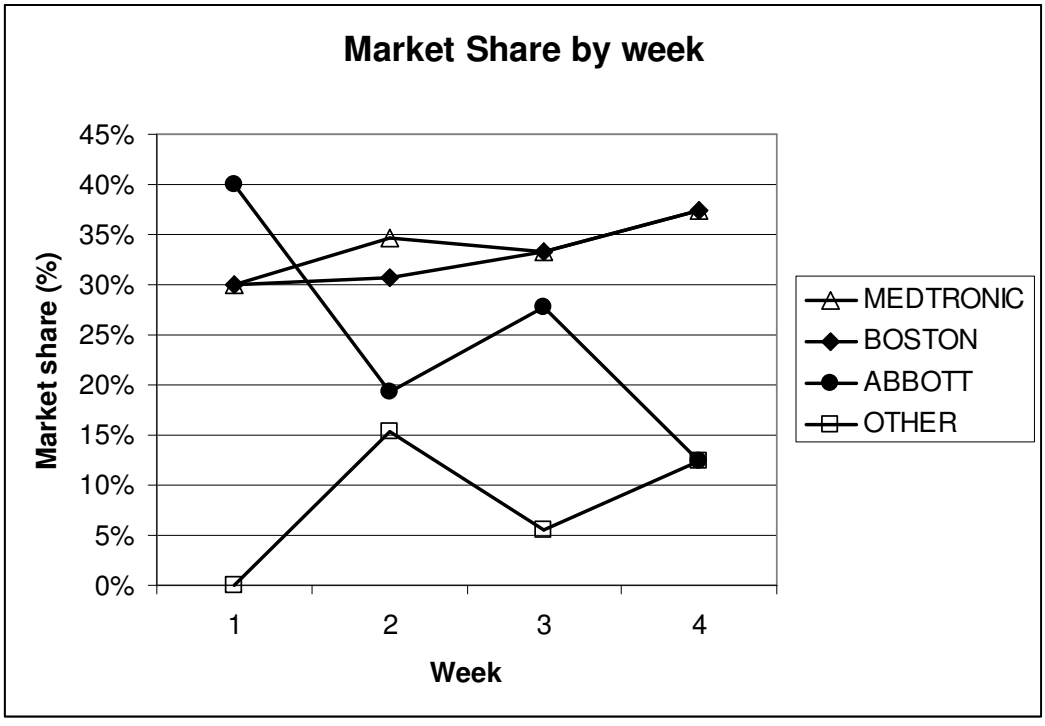

Figure 5.2 Weekly market share by supplier

Figure 5.3 shows the average weekly purchase frequency for all suppliers. The average weekly purchase frequency shows some marked week to week variation at category level and at an individual supplier level although the trend for category purchases through the period is relatively steady around an average of 2.6 purchases per requisitioner. It should also be noted that although the number of purchases of the category in Week 1 is below average (see Table 5.1), the purchase frequency for the category lies close to the average frequency of 2.6. This shows that the reduced number of purchases is due to fewer purchasers rather than a reduction in the frequency of buying. In fact, only four requisitioners make purchases in Week 1, about half of the average number of purchasers per week over the whole period (Table 5.1).

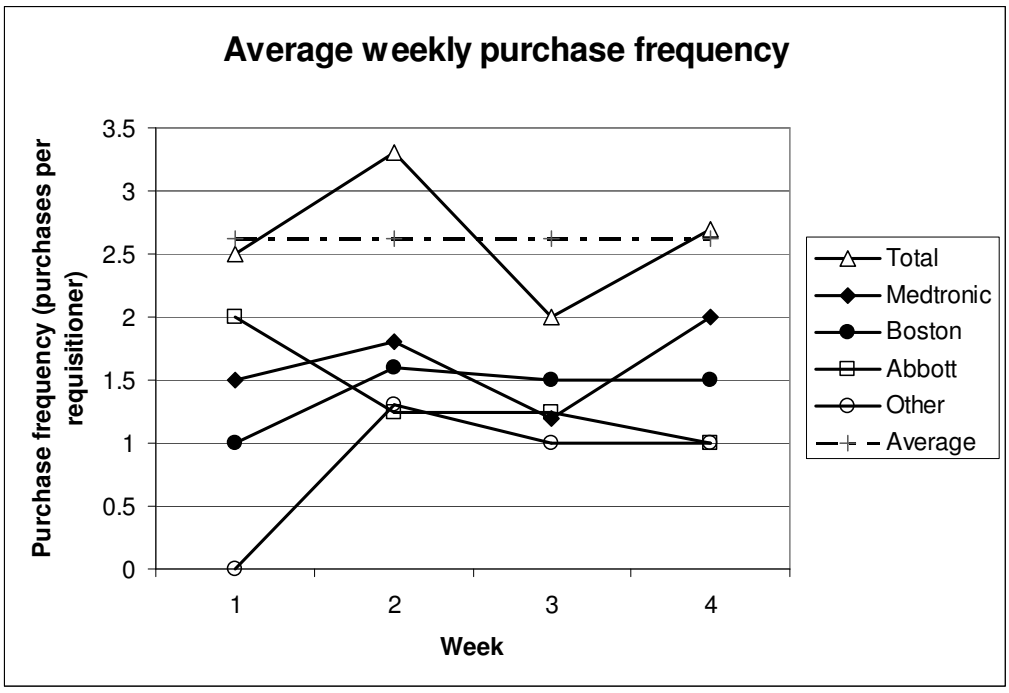

Figure 5.3 Average weekly purchase frequency by supplier

Although there is some week to week variability, particularly in the market shares for the various suppliers, a visual comparison of the purchase frequency against the four week average (Figure 5.3) shows that the average purchase frequency for the category is approximately stationary. For the subsequent

analysis, an average two week period is used as the base period in order to smooth out the week to week variations.

5.2.3 Summary Statistics

Table 5.3 a-c shows observed summary statistics for an average week, an average two week period and the whole four week period. The market shares are constant across all the summary data sets as each table is averaged across the entire four weeks. ANY is the combined data for the category, regardless of supplier.

Table 5.3 Summary statistics

(a) Average 1 week summary statistics

Supplier	Number of Requisitions	Number of Requisitioners	Requisition Frequency	Penetration (%)	Market Share
MEDTRONIC	6.0	3.8	1.6	9.4%	34.3%
BOSTON	5.8	4.0	1.4	10.0%	32.9%
ABBOTT	4.0	3.0	1.3	7.5%	22.9%
OTHER	1.8	1.5	1.2	3.8%	10.0%
ANY	17.5	6.8	2.6	16.9%	

(b) Average 2 week summary statistics

Supplier	Number of Requisitions	Number of Requisitioners	Requisition Frequency	Penetration (%)	Market Share
MEDTRONIC	12.0	6.5	1.8	16.3%	34.3%
BOSTON	11.5	6.0	1.9	15.0%	32.9%
ABBOTT	8.0	4.5	1.8	11.3%	22.9%
OTHER	3.5	2.5	1.4	6.3%	10.0%
ANY	35.0	10.5	3.3	26.3%	

(c) Average 4 week summary statistics

Supplier	Number of Requisitions	Number of Requisitioners	Requisition Frequency	Penetration (%)	Market Share
MEDTRONIC	24.0	9.0	2.7	22.5%	34.3%
BOSTON	23.0	10.0	2.3	25.0%	32.9%
ABBOTT	16.0	6.0	2.7	15.0%	22.9%
OTHER	7.0	4.0	1.8	10.0%	10.0%
ANY	70.0	14.0	5.0	35.0%	

The typical patterns of a Dirichlet market can be seen in all time periods but they are most clear in the 4 week summary tables. The average requisition frequency

is quite similar across all the suppliers although the market shares and penetrations differ markedly. The exception is the "Others" composite supplier where the combination of low market share and low purchase frequency is the frequently observed "Double Jeopardy" pattern where small suppliers not only have fewer purchasers but these purchasers also purchase less frequently.

Penetration is the proportion of the relevant population that makes a purchase. With data taken from purchase order data, only those members of the population who make a purchase are included in the data set and hence a suitable relevant population must be assumed. In this case the relevant population of requisitioners is assumed to be 40. Table 5.3 shows how the penetration increases as the time period under analysis increases.

The number of requisitioners for ANY supplier is generally lower than the simple sum of buyers of all products. This shows that several requisitioners split their purchases between more than one supplier in the time period.

5.3 Data Analysis and Interpretation

5.3.1 Sample Frame

The description of the data above has shown that the purchasing behaviours show many of the patterns that would be expected in a Dirichlet market. The model is operationalised using an average two week period to smooth out the week to week variation in the observed data. The base period will be used to predict performance measures for periods of 1, 2 and 4 weeks to assess how well the NBD-Dirichlet can describe and predict the observed performance.

5.3.2 Purchase Distributions

The proportion of purchasers making 0, 1, 2, 3, … purchases from each supplier, and of the category in the two week time period are predicted using the NBD model and compared to the observed distributions. A simple correlation test and the magnitude of the observed deviations are used to assess the fit. The number of purchasers that make no purchases in the time period is used for fitting the model and therefore is not included in the test for goodness of fit.

Table 5.4 Comparison between observed and predicted distribution of purchases

Period	Supplier	Correlation between observed and theoretical distributions (r)	Mean Absolute Deviation between observed and theoretical distributions
1 week	MEDTRONIC	0.98	2.6
	BOSTON	0.96	4.6
	ABBOTT	0.96	3.6
	OTHERS	1.00	1.1
	ANY	0.93	4.8
2 weeks	MEDTRONIC	0.96	3.6
	BOSTON	0.99	2.1
	ABBOTT	0.67	8.5
	OTHERS	0.91	5.3
	ANY	0.91	4.7
4 weeks	MEDTRONIC	0.92	4.1
	BOSTON	0.94	5.7
	ABBOTT	0.44	11.7
	OTHERS	0.92	5.1
	ANY	0.91	4.0

Table 5.4 presents the results of the goodness of fit tests. In 13 of the 15 cases the correlation coefficient is greater than 0.9 and the mean absolute deviation is small.

Plotting the observed and expected distributions (Figures 5.4 to 5.8) also shows the generally good fit between the model predictions and the observed data.

From the plotted distributions the relatively poor fit for Abbott at 2 weeks and 4 weeks can be observed. The model overestimates the number of once only buyers and underestimates the number of heavier buyers. For the other suppliers and for the whole category the fit is good with no evidence of systematic bias. In a relatively small buying population a single purchaser can represent a large percentage of the population such that the observed distribution is not smooth.

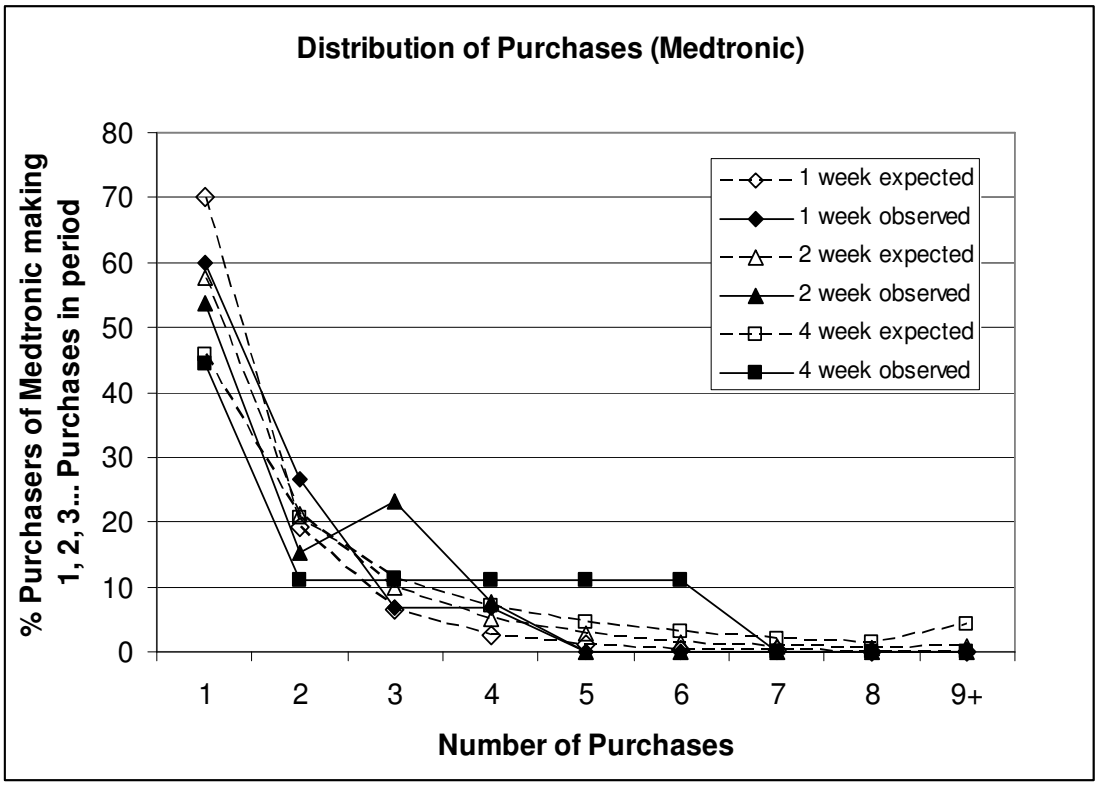

Figure 5.4 Expected and observed distribution of purchases (Medtronic)

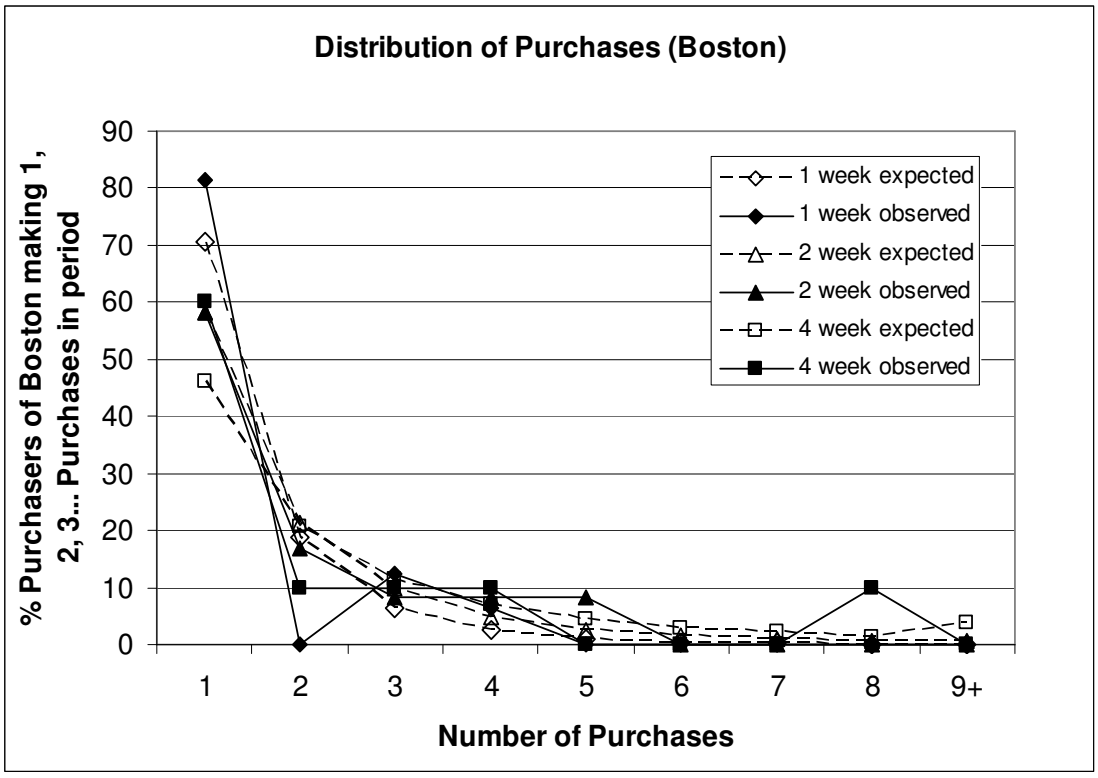

Figure 5.5 **Expected and observed distribution of purchases (Boston)**

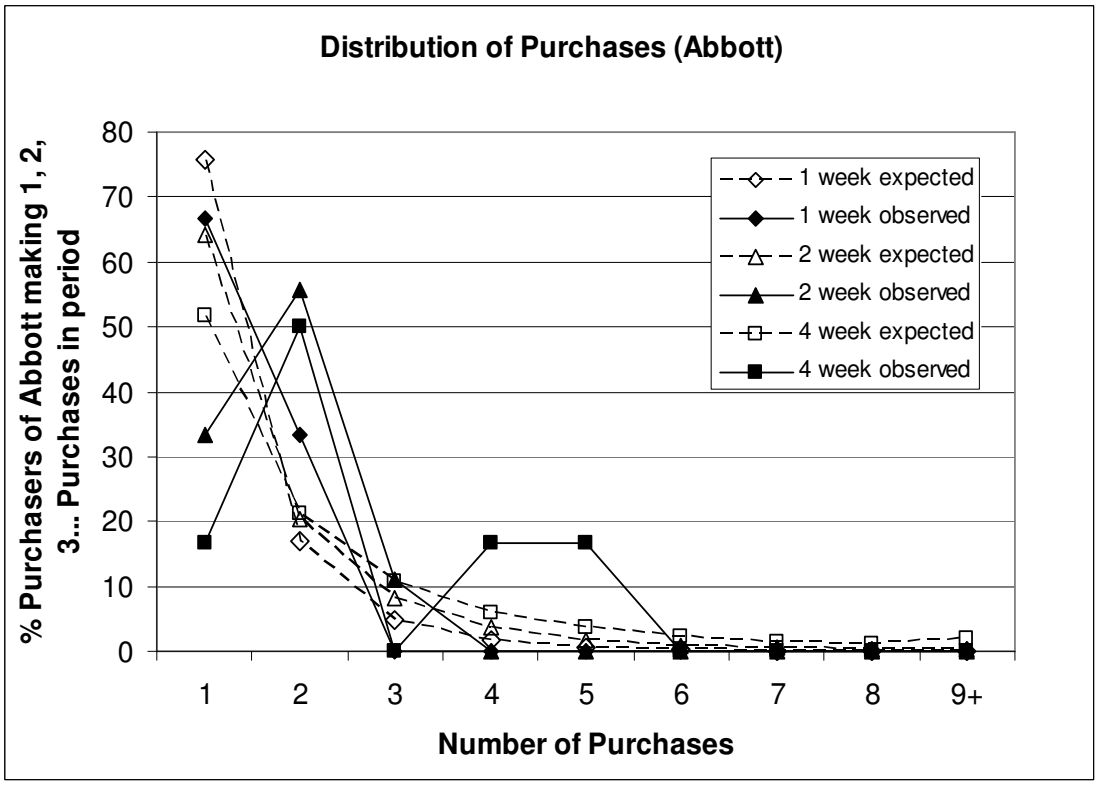

Figure 5.6 **Expected and observed distribution of purchases (Abbott)**

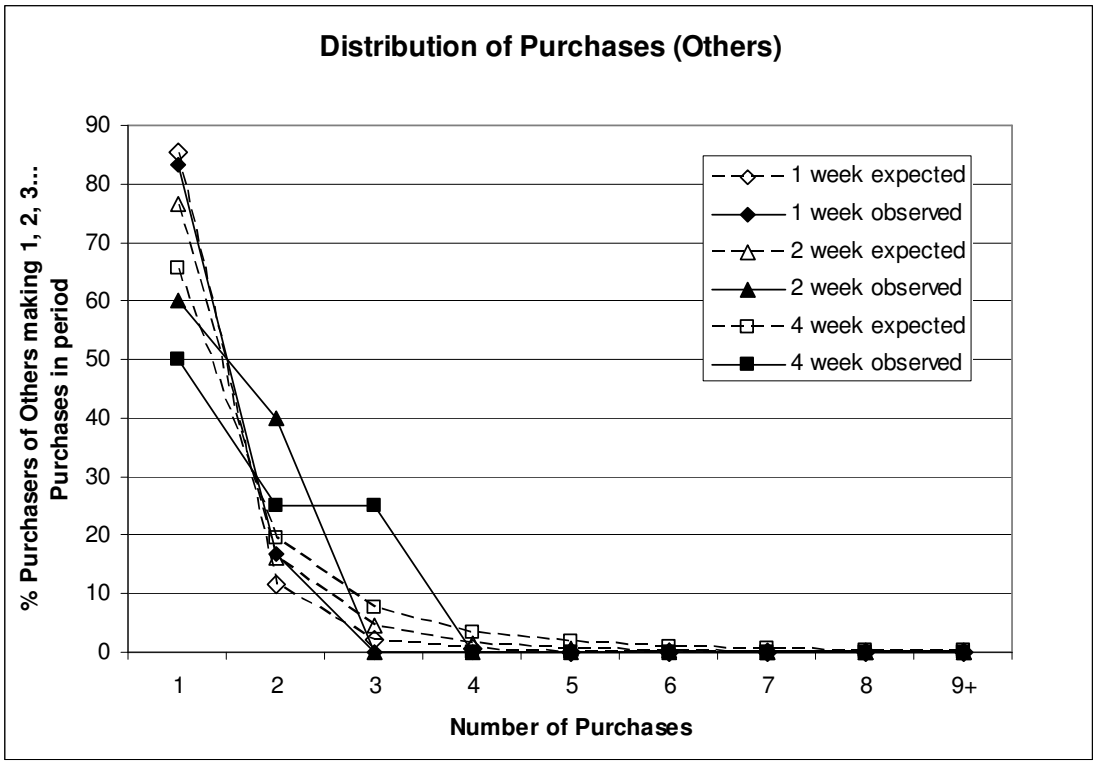

Figure 5.7 **Expected and observed distribution of purchases (Others)**

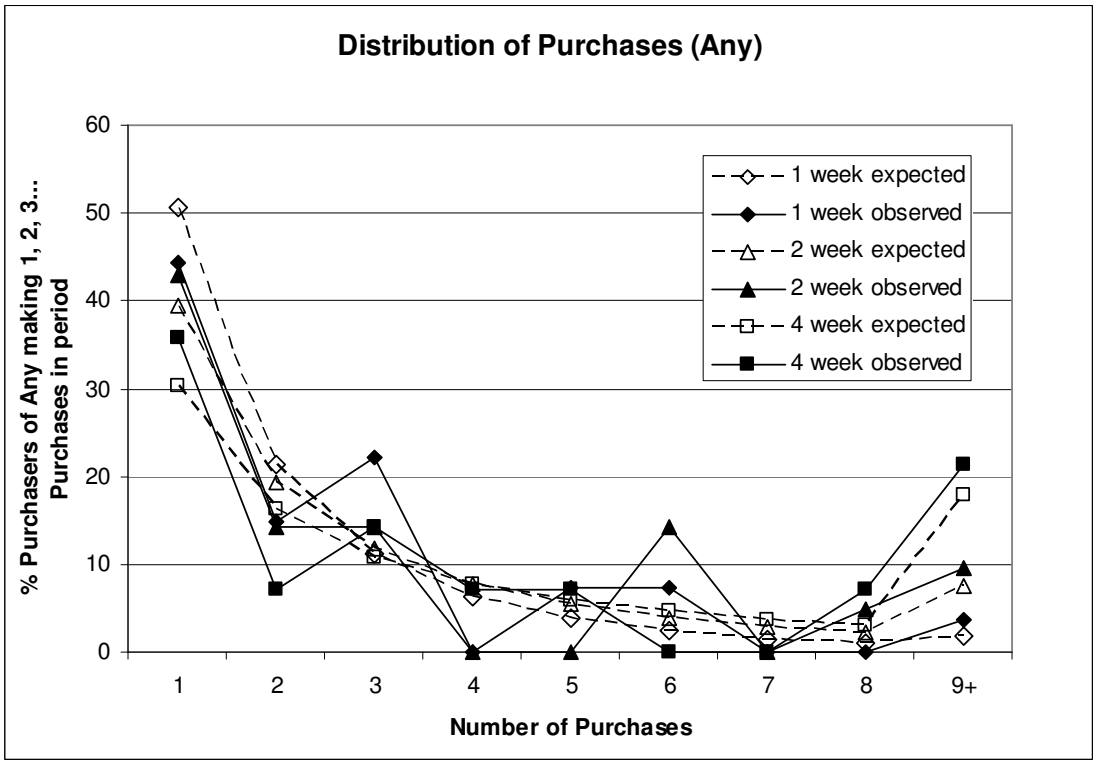

Figure 5.8 **Expected and observed distribution of purchases for product category (Any)**

5.3.3 Penetration Growth

The observed and expected 1 week, 2 week and 4 week penetrations and purchase frequencies are presented in Table 5.5.

Table 5.5 Observed and theoretical performance measures

Period	Supplier	Penetration		Purchase Frequency	
		O	T	**O**	T
1 week	Medtronic	**9.4%**	10.0%	**1.6**	1.5
	Boston	**10.0%**	9.7%	**1.4**	1.5
	Abbott	**7.5%**	7.4%	**1.3**	1.4
	Others	**3.8%**	3.7%	**1.2**	1.2
	Average Supplier	**7.7%**	7.7%	1.4	1.4
	Correlation, r	0.99		0.91	
	Mean Absolute Deviation	0.3%		0.1	
2 weeks	Medtronic	**16.3%**	15.5%	**1.9**	1.9
	Boston	**15.0%**	15.1%	**1.9**	1.9
	Abbott	**11.3%**	12.0%	**1.8**	1.7
	Others	**6.3%**	6.5%	**1.4**	1.4
	Average Supplier	**12.2%**	12.3%	1.8	1.7
	Correlation, r	0.99		0.98	
	Mean Absolute Deviation	0.5%		0.0	
4 weeks	Medtronic	**22.5%**	22.1%	**2.7**	2.7
	Boston	**25.0%**	21.6%	**2.3**	2.7
	Abbott	**15.0%**	18.0%	**2.7**	2.2
	Others	**10.0%**	10.6%	**1.8**	1.7
	Average Supplier	**18.1%**	18.1%	2.4	2.3
	Correlation, r	0.94		0.67	
	Mean Absolute Deviation	1.9%		0.3	

It can be seen that the fit is generally good with the correlation coefficients greater than 0.9 and the mean absolute deviation corresponding to a percentage error of less than 10% for the 1 week and 2 week data. The fit is less good for the 4 week data, due to higher than expected penetration and lower than

expected purchase frequency for Boston and lower than expected penetration and higher than expected purchase frequency for Abbott. Boston has a larger than expected number of once-only buyers (see Figure 5.5) which affects both the observed penetration and purchase frequency. The underestimation of Abbott's heavier buyers has already been noted in the previous section.

5.3.4 Share of Category Requirements

The Share of Category Requirements (SCR) measures the extent to which the particular supplier fulfils the customer's purchases of the category. A SCR of 100% would mean that all customers of the supplier purchased from the supplier all of the time. A SCR of 50% would mean that customers fulfilled their requirements from other suppliers half of the time. Table 5.6 shows that the dominant suppliers have SCRs less than 50%, i.e. buyers of these suppliers tend to buy from other suppliers more often than they buy from the particular supplier.

The observed data (Table 5.6) shows SCRs generally in line with the model predictions except for Others. The relatively low purchase frequencies for the supplier Others means that the buyers of this group of suppliers often make only a single purchase, giving no opportunity to split purchases between suppliers. Table 5.6 also shows a much improved fit for the SCR for a "heavy" and "light" purchasing segment, chosen to be those buyers who purchase more than once per week and once per week or less respectively. The heavy segment does not purchase from the Others suppliers at all. This exclusion of the smaller suppliers from the heavy buyers' repertoires is an unusual pattern. The Natural Monopoly phenomenon (McPhee, 1963) predicts that heavier users of a category

are more likely to use smaller suppliers because they have more opportunity and tend to be well-informed consumers. Previous studies (Fader & Schmittlein, 1993) have identified excess behavioural loyalty associated with high market share suppliers – the association of excess loyalty with small suppliers is atypical. They suggested that the excess loyalty could be attributed to underlying market segmentation with particular reference to brand availability. The observed patterns in this case suggest the existence of purchasing segments with distinct behaviours, perhaps a purchase repertoire constrained by a restricted set of framework purchasing agreements.

Table 5.6 Share of category requirements

Period	Supplier	Entire Population		Heavy Segment		Light Segment	
		O	T	**O**	T	**O**	T
	Medtronic	**45.0%**	50.8%	**41.7%**	44.3%	**57.1%**	77.9%
	Boston	**42.6%**	49.8%	**37.5%**	41.7%	**71.4%**	79.7%
	Abbott	**34.0%**	42.8%	**31.9%**	36.6%	**33.3%**	73.1%
1 week	Others	**66.7%**	33.9%	**0.0%**	0.0%	**87.5%**	84.3%
	Average Supplier	**47.1%**	44.3%	**27.8%**	30.7%	**62.3%**	78.8%
	Correlation, r	-0.68		1.00		0.99	
	Mean Absolute Deviation	13.7%		2.94%		16.93%	
	Medtronic	**39.4%**	43.6%	**37.7%**	41.0%	**50.0%**	65.5%
	Boston	**41.7%**	42.4%	**36.7%**	38.2%	**71.4%**	68.2%
	Abbott	**28.5%**	34.2%	**29.4%**	32.8%	**33.3%**	58.0%
2 weeks	Others	**87.5%**	24.1%	**0.0%**	0.0%	**87.5%**	75.4%
	Average Supplier	**49.3%**	36.1%	**26.0%**	28.0%	**60.6%**	66.8%
	Correlation, r	-0.77		1.00		0.98	
	Mean Absolute Deviation	18.5%		1.74%		11.56%	
4 weeks	Medtronic	**36.9%**	39.1%	**37.7%**	39.1%	**33.3%**	52.5%
	Boston	**37.7%**	37.8%	**34.0%**	36.3%	**62.5%**	56.1%
	Abbott	**28.6%**	29.0%	**28.3%**	30.7%	**33.3%**	42.5%
	Others	**77.8%**	17.9%	**0.0%**	0.0%	**77.8%**	65.9%
	Average Supplier	**45.3%**	31.0%	**25.0%**	26.5%	**51.7%**	54.3%
	Correlation, r	-0.79		1.00		0.89	
	Mean Absolute Deviation	15.7%		1.56%		7.51%	

5.3.5 Sole Buyers

The incidence of sole loyalty (the proportion of the purchasers of a supplier who buy only from that single supplier) can also be predicted and is tabulated in Table 5.7.

Table 5.7 Sole Buying

Period	Supplier	Sole Buyers		Sole Buyer Purchase Frequency	
		O	T	**O**	T
1 week	Medtronic	**22.5%**	40.0%	**0.6**	1.2
	Boston	**33.3%**	39.2%	**0.8**	1.2
	Abbott	**6.3%**	34.1%	**0.3**	1.1
	Others	**62.5%**	28.0%	**0.8**	1.1
	Average Supplier	**31.2%**	35.3%	0.6	1.2
	Correlation, r	-0.59		0.37	
	Mean Absolute Deviation	21.4%		0.5	
2 weeks	Medtronic	**22.6%**	28.3%	**1.3**	1.3
	Boston	**28.6%**	27.5%	**0.5**	1.2
	Abbott	**0.0%**	22.7%	**0.0**	1.2
	Others	**75.0%**	17.1%	**1.2**	1.1
	Average Supplier	**31.6%**	23.9%	0.8	1.2
	Correlation, r	-0.63		0.07	
	Mean Absolute Deviation	21.9%		0.5	
4 weeks	Medtronic	**0.0%**	20.0%	**0.0**	1.3
	Boston	**30.0%**	19.3%	**1.0**	1.3
	Abbott	**0.0%**	15.1%	**0.0**	1.2
	Others	**50.0%**	10.3%	**1.0**	1.1
	Average Supplier	**20.0%**	16.2%	0.5	1.2
	Correlation, r	-0.61		-0.30	
	Mean Absolute Deviation	21.4%		0.7	

The incidence of sole loyalty is rather low and the purchase frequency of those buyers that are solely loyal is much lower than the average for the whole

population. There are some marked deviations from the model predictions. Abbott shows much lower sole loyalty than the model prediction – as is evidenced by the apparent decline in market share though the month. By contrast Others shows a much higher incidence of sole loyalty, again an effect of the aggregation of suppliers and low purchase frequency providing less opportunity for changing supplier.

5.3.5.1 Duplication of Purchase

The analysis of duplication of purchase shows the other suppliers that are also used by purchasers of a particular supplier within an average two week period. It can be seen that there is considerable duplication of purchase between the major suppliers and much less with the Others supplier. This supports the observation that buyers of the dominant suppliers may be constrained in their choices by negotiated purchasing agreements.

Table 5.8 Observed duplication of purchase

	Who also purchase from:			
First Purchase	Second Purchase			
Buyers who purchase from:	Medtronic	Boston	Abbott	Other
Medtronic		61.5%	69.2%	7.7%
Boston	66.7%		66.7%	0.0%
Abbott	100.0%	88.9%		0.0%
Others	20.0%	0.0%	0.0%	
Average observed duplication	62.2%	50.1%	45.3%	2.6%

5.4 Discussion

The analysis of the observed purchasing behaviours in the single trust coronary stent case has shown that the reported purchasing behaviours can be satisfactorily modelled using the NBD-Dirichlet. The fit is generally good

although the loyalty behaviours, Share of Category Requirements and incidence of sole buying, show a consistent over-estimation of loyalty for the smaller suppliers. These deviations are attributed to the distinct purchasing behaviours of a heavy purchasing segment and a light purchasing segment. Such a pattern has been observed previously in the analysis of foreign exchange services (Bowman & Lele-Pingle, 1997). In particular the smaller suppliers are purchased exclusively by the light purchasing segment which purchases less frequently and hence has fewer opportunities to be disloyal than the heavier purchasers.

5.4.1 Dirichlet Assumptions

The single trust coronary stent data set is approximately stationary over the four week analysis period although there is some week to week variability, including an apparent decline in market share for Abbott. An average two week base period is used to smooth some of this variability such that the Dirichlet assumption of stationary markets is assumed to hold.

The second assumption that underpins the Dirichlet analysis is lack of partitioning. In the analysis of the stent purchasing data, segments based on purchase frequency (heavy and light purchasers) have been identified as the source of deviations between the model predictions and observed behaviour, in particular for the share of category requirement. The heavy purchasers in particular purchase only from the major suppliers. This violates a further Dirichlet assumption, that of the independence of purchase incidence and supplier choice. The heavier buyers appear to be buying from a restricted repertoire, constrained by supplier framework agreements.

5.4.2 Theoretical Implications

The analysis of the single trust coronary stent case has shown that the observed purchasing behaviour can be satisfactorily explained and predicted using the NBD-Dirichlet, representing a replication of the model in a healthcare procurement environment.

5.4.2.1 Extension of the NBD-Dirichlet Empirical Generalisation

The purchasing behaviours of individual coronary stent requisitioners in the single trust exhibit the regular patterns of buyer behaviour that have been observed in many different markets (Ehrenberg et al, 2004). These regular patterns include the observations that suppliers in the category typically have very different market shares and penetrations but the purchase frequency for each supplier is approximately constant. The Double Jeopardy phenomenon where smaller suppliers tend to be purchased less frequently than the larger suppliers (McPhee, 1963) is also observed.

The heavier purchasers of the category buy only rarely from the smaller suppliers. This unusual pattern is an initial deviation from the typical Dirichlet patterns and is attributed to constrained supplier choice and availability (Fader & Schmittlein, 1993). Such constraints can arise from supplier framework agreements that result in restricted repertoires.

The patterns of observed supplier loyalty in the coronary stent category show the typical patterns of a Dirichlet repertoire market (Sharp et al, 2002) where the buyers of a particular supplier tend to buy from other suppliers quite often. The share of category requirements for the average supplier is less than 50%. This is typical of competitive markets where buyers are highly experienced and have

well established supplier choice propensities such that the Dirichlet's zero-order assumption holds (Ehrenberg et al, 2004).

Partitioning of the market with a segment of high frequency buyers dominating the observed purchase behaviours is particularly noticeable. Others has a much higher share of category requirements than that predicted by the Dirichlet model. This is an effect of the exclusion of Others from the repertoires of the heavy suppliers and the number of purchases used to operationalise the model. Others is bought exclusively by the lighter purchasers who have few opportunities to use alternative suppliers, leading to high observed loyalty measures. Such segmentation violates the Dirichlet distributional assumptions of lack of partitioning and the independence of supplier choices and purchase frequency (Sharp & Driesener, 2000).

The analysis shows that the NBD-Dirichlet describes and predicts the observed purchasing patterns within much the same limits of scatter as previous Dirichlet studies (Ehrenberg, 1994), satisfying the test of "significant sameness" (Barwise, 1995).

5.4.3 Managerial Implications

The theoretical predictions of the NBD-Dirichlet model provide norms and benchmarks against which to assess current behaviours and to monitor the impact of managerial interventions (Ehrenberg & Sharp, 2000). The managerial implications of the model are discussed below.

5.4.4 Buyer Repertoires

Buyers in competitive Dirichlet type markets will typically purchase from a repertoire of several suppliers with fixed long term purchase frequencies and steady supplier choice probabilities (Goodhardt et al, 1984). The single trust coronary stent case demonstrates how preferred supply agreements lead to restricted buyer repertoires. In the single trust case the restricted repertoires appear well established and the heavy buying segment splits their purchases between the suppliers in this constrained choice set.

5.4.4.1 Supplier Loyalty

The loyalty shown to particular suppliers in a competitive Dirichlet market tends to be similar across all suppliers. Buyers appear to welcome variety and choice (Ehrenberg et al, 2004), a behavioural pattern that is advantageous to purchasing managers seeking to encourage competition and choice in a particular category. Experienced buyers, such as those in the single trust cardiac stent case already exhibit split loyalty behaviour, albeit within a restricted repertoire.

5.4.4.2 Dirichlet Predictions

The Dirichlet model provides theoretical norms and benchmarks that can be used to assess patterns of behaviour (Ehrenberg et al, 2004). The purchasing manager can use the model in a category audit to compare the observed behaviours with the Dirichlet predictions and identify deviations that may indicate non-compliance or maverick purchasing behaviour. The analysis of the single trust coronary stent data appears to show rather well-behaved purchasers but possible deviations could include unexpectedly high purchase frequency for a particular supplier, perhaps in response to a local promotion or unexpectedly

high penetration for one of the smaller suppliers, indicating some maverick purchasing. The analysis of purchase behaviours at an individual requisitioner level is a powerful tool for managing compliance with purchasing agreements.

5.5 Summary

This chapter has presented the analysis of the coronary stent purchasing data set from the single NHS trust.. The analysis shows that even with a relatively short analysis period, the NBD-Dirichlet describes and predicts the observed purchasing patterns with good accuracy. Segmenting the population into a heavy (high frequency) segment that purchases from a restricted repertoire of suppliers and a light purchasing segment is shown to improve the accuracy of the predictions.

The pilot study confirms the coronary stent category as suitable for analysis and demonstrates that stent purchasing patterns in a single hospital over a limited time period can be modelled using the NBD-Dirichlet. The number of suppliers, the number of buyers and their experience and the frequency of purchase of the coronary stent category make it an interesting category for further analysis. In addition, the ability of the Dirichlet to accurately model stent purchase data has been established, providing a sound basis for extension of the research to the more complex longitudinal analysis of the purchasing patterns in the collaborative purchasing hub.

6 Modelling Ureteral Stent Procurement in a Collaborative Purchasing Hub

6.1 Introduction

Data from three full purchasing years (April 2006 to March 2008) for reporting trusts in a Collaborative Purchasing Hub (CPH) have been analysed. As one of the assumptions underpinning the Dirichlet model is that of non-partitioned markets, the full data set has been categorised into different categories of stent. Two major stent categories, ureteral and coronary, are analysed, allowing a comparison between purchasing patterns in the two categories.

This chapter deals with ureteral stents, the largest category by number of purchase occasions. The coronary stent case will be presented in Chapter 7. A description of the data set is followed by the parameterisation of the model and testing for goodness of fit. It is shown that the NBD-Dirichlet is able to satisfactorily describe and predict the observed purchasing behaviours. This is a substantial extension of the model into the analysis of dynamic behaviour in a collaborative public procurement purchasing environment.

The model provides behaviour benchmarks against which the observed behaviours are assessed. Systematic deviations from the model predictions are analysed in the context of the Dirichlet assumptions of stationarity and lack of partitioning. It is shown that over the three year analysis period, there is considerable non-stationarity and two distinct segments based on purchase frequency are identified. There is a major change in the relative market

positions of the two dominant suppliers during the analysis period. However by choosing shorter time periods for analysis, the stability assumption can be approximately met and a comparison between successive time periods can be made to track the dynamic development of the market in a series of snapshots.

In the cross-sectional analysis, deviations between the observed behavioural patterns and those predicted by the model are explained by the existence of a high purchase frequency (heavy purchasers) segment and a low purchase frequency segment (light purchasers) with distinctive and different purchasing behaviours. The longitudinal analysis tracks the changes in market position of the two dominant suppliers. There has been no purchasing management intervention in this category and the interviews with the procurement executives were unable to provide any qualitative data other than to comment that the observed changes are attributed to a ramp up in sales effort by one of the suppliers.

The analysis shows how deviations from benchmark behaviours can be used to identify targets for purchasing management intervention, to suggest strategies for intervention and to either track the progress of such interventions or track changes in the market dynamics as a result of supplier activity. As will be seen in Chapter 8, this observation has implications for public sector procurement departments seeking to rationalise supply relationships while nurturing innovation and diversity in the supply base.

6.2 Description of the Data

6.2.1 Purchases by Requisitioner

During the three year period, 45 purchasers made 591 purchases of the category, with two buyers alone accounting for almost half of all purchases (47.4%) as shown in Figure 6.1. There is a long tail of infrequent buyers with 28 buyers making 5 or fewer purchases in the three years.

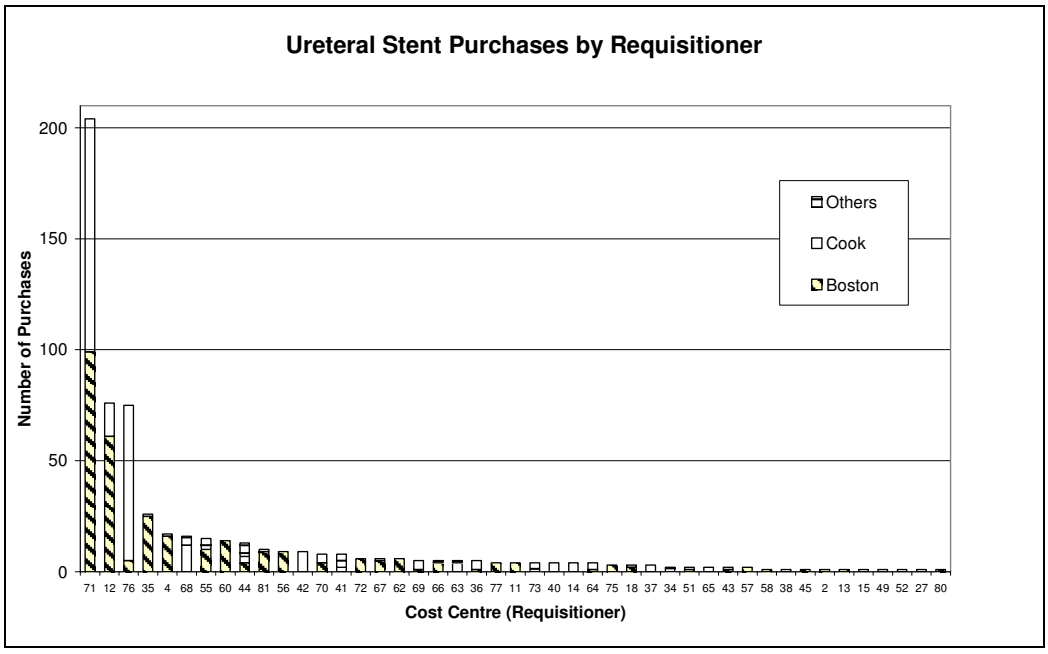

Figure 6.1 Ureteral stent purchases by requisitioner

Excluding these infrequent buyers, who have less opportunity to change supplier, only 5 buyers fulfilled their requirements from a single supplier. The top five buyers, accounting for 67% of purchase occasions, only purchased from the two dominant suppliers in the category. The purchase choices of the remaining 40 buyers are shown in more detail in Figure 6.2 and demonstrate more diversity in supplier choice than the heavier purchasers

.

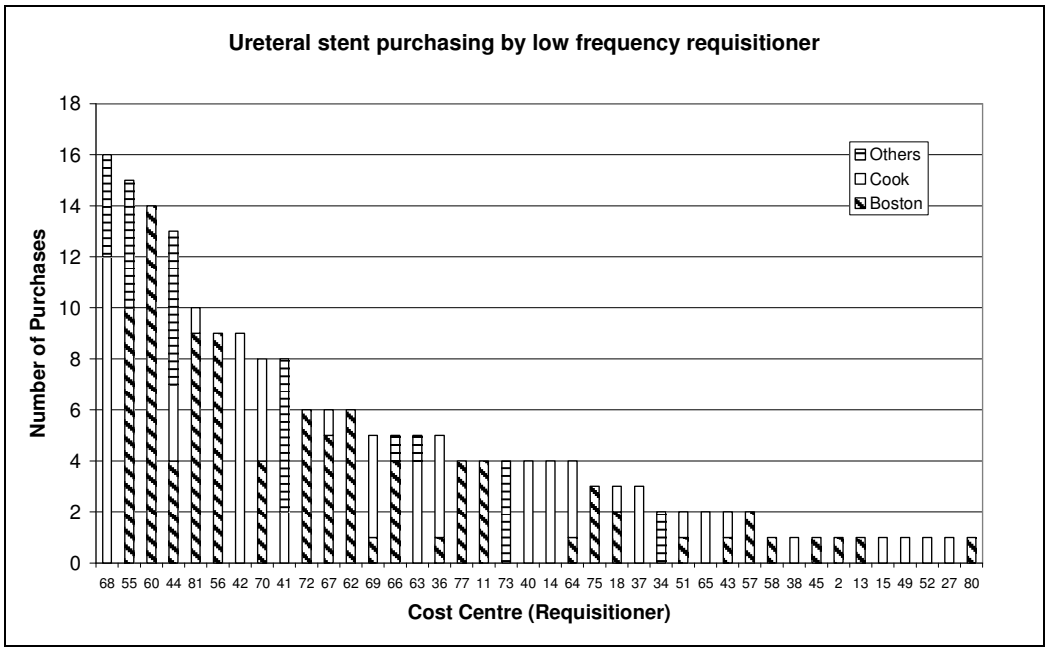

Figure 6.2 Ureteral stent purchases by low frequency requisitioner

The observed tendency for the heaviest purchasers to prefer the main suppliers in a category has already been noted in the analysis of the pilot data (Chapter 5) and is a preliminary indication of deviations from the Dirichlet model where the expectation would be for the heaviest buyers to have greatest opportunity to use some of the smaller suppliers, consistent with the phenomenon of Natural Monopoly (McPhee, 1963) where consumers of smaller suppliers are more likely to be heavy consumers of the category (Elberse, 2007). The near exclusion of smaller suppliers from the larger buyers' repertoires is consistent with the restrictive effect of preferred supplier agreements on buyer repertoires but violates the Dirichlet assumption of independence of supplier choice and purchase incidence.

6.2.1.1 Poisson Assumption

The NBD is based on the assumption that successive purchases by individual buyers are spread over time with a constant mean purchase frequency. If this

assumption holds, the purchase distribution for an individual purchaser can be described by a Poisson process with mean μ equal to the stable long run purchase frequency (see Section 3.4.2). Half yearly purchases for each cost centre are tabulated in Table 6.1, demonstrating that the heaviest buyers (accounting for 60% of purchases) do exhibit a stable purchase frequency throughout the three year period.

Table 6.1 Purchases by requisitioner (2006 – 2008)

	2006		2007		2008		
Cost Centre	H1	H2	H1	H2	H1	H2	Average
71	25	30	40	30	40	28	32.2
76	11	10	11	11	11	17	11.8
12	4	6	15	19	15	12	11.8
35		7	13	4			4.0
4			11	6			2.8
68			5	5	1	5	2.7
60	4	3	3	3			2.2
55	1	3	5	2	1	1	2.2
44	2	3		3	2	3	2.2
81			2	8			1.7
56	2	2	2	1		2	1.5
42					2	6	1.3
70	2	6					1.3
41		1	1	1	2	3	1.3
72	2	2		2			1.0
69						5	0.8
63			2	3			0.8
36	4	1					0.8
62					2	3	0.8
77			4				0.7
73			3	1			0.7
14					2	2	0.7
66	1	1	1	1			0.7
11				2	1	1	0.7
40				2	2		0.7
37					1	2	0.5
18	1			2			0.5
67						2	0.3
64			1	1			0.3
34				2			0.3
43					1	1	0.3
75				1		1	0.3
51			1	1			0.3
57		1	1				0.3
65					1		0.2
80	1						0.2
38	1						0.2
27	1						0.2
15		1					0.2
13		1					0.2
58			1				0.2
2			1				0.2
49				1			0.2
45			1				0.2
52					1		0.2
Total Purchases	62	78	124	112	85	94	92.5
Total Requisitioners	15	16	21	24	16	17	18.2

There is more observed variability in those buyers that purchase less frequently, with some purchasers active for only a portion of the overall time period but exhibiting a relatively constant purchase frequency within that period.

6.2.2 Purchases by Supplier

Two suppliers, Boston Scientific and Cook Medical, together account for 562 of the 591 purchase orders, 95% of the total (Table 6.2).

Table 6.2 Ureteral stent purchases by supplier

	BOSTON	COOK	ROCKET	BARD	EUROMEDICAL	TOTAL
2006	102	40	4	4	0	150
2007	127	105	3	6	6	247
2008	73	115	5	1	0	194
TOTAL	302	260	12	11	6	591

Table 6.2 also shows a noticeable increase in purchases of Cook over the three years such that Cook has displaced Boston as the dominant supplier by 2008. This change in Cook's position can also be seen in Figure 6.3 which plots the development in market share for the five suppliers. It can be seen that a period of relative stability when Boston enjoyed a market share of about 70% with Cook at about 25% started to change towards the end of 2006 (beginning of calendar year 2007). This was followed by about 9 months of volatility before another period of relative stability between Month 18 and Month 27. The remaining months show a sustained but variable market share advantage for Cook. Discussions with purchasing executives in the hub have confirmed that there has been no purchasing management intervention in this category and that the changes in supplier position are the result of increased promotional activity by Cook.

Analysis of the monthly purchase frequency over the same period shows that this increase in market share for Cook is accompanied by a slight increase in purchase frequency over the same period (Figure 6.4).

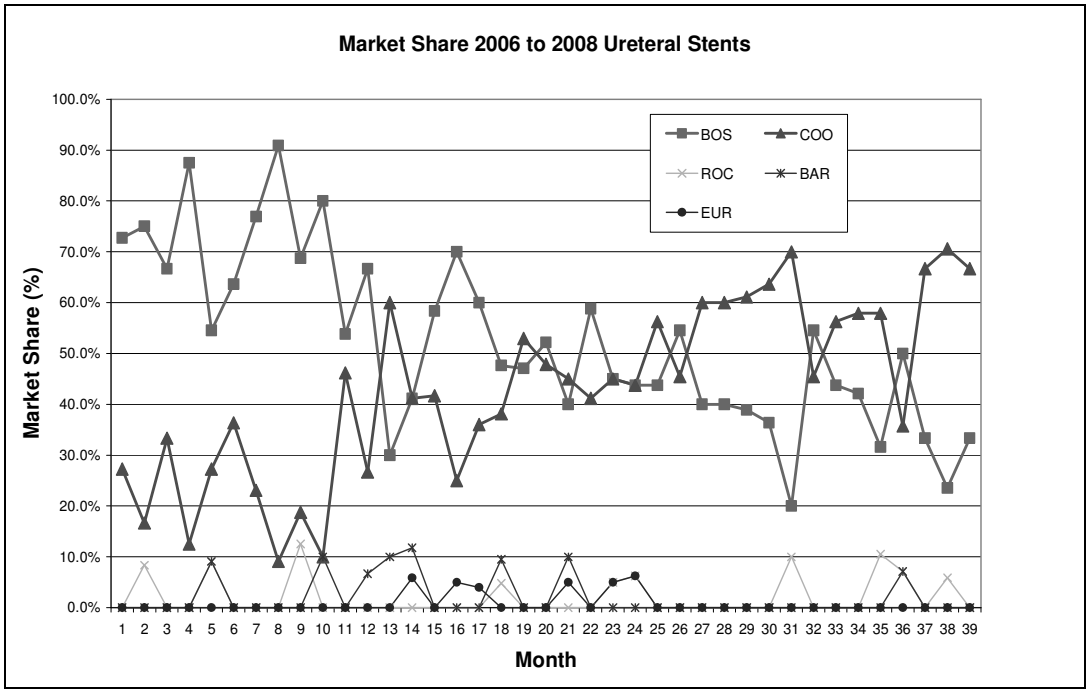

Figure 6.3 Monthly market share by supplier

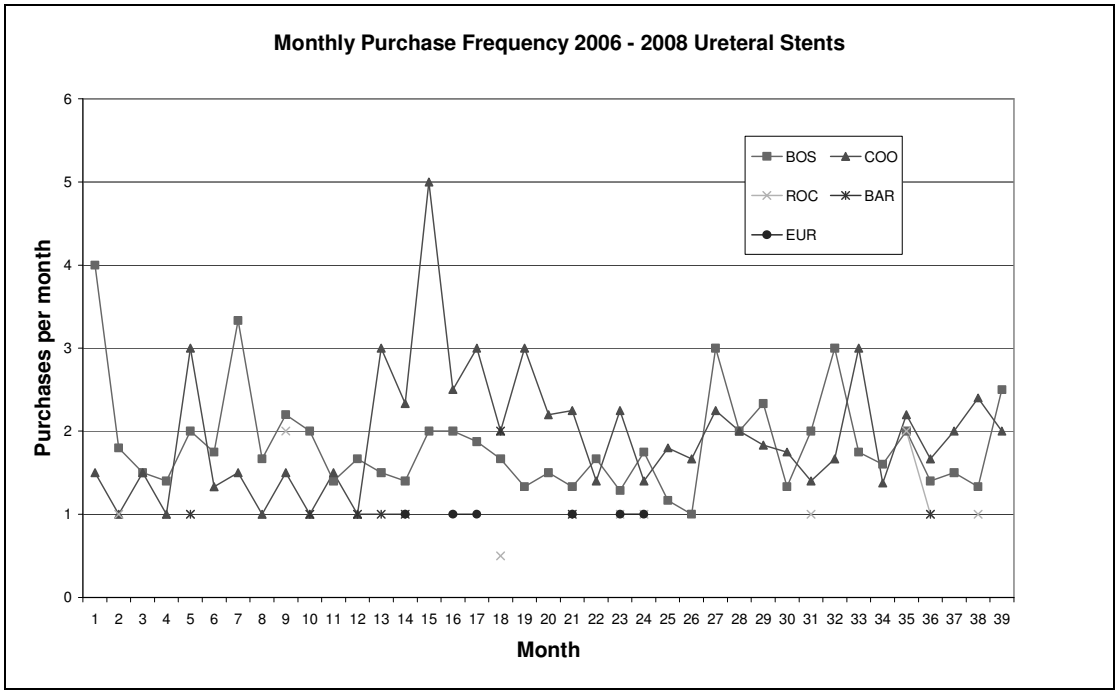

Figure 6.4 Monthly purchase frequency by supplier

Figures 6.3 and 6.4 show that the market is non-stationary with a clear trend through the three year period as Cook displaces Boston as the dominant supplier. Tables 6.3 and 6.4 compare the predicted purchasing behaviour in six months and thirty-six months based on the first six months of the data set and on an average six month base period (averaged over the 36 month data set).

Table 6.3 Dirichlet predictions (average six months, first six months)

		Penetration		Purchase Frequency		SCR	
Base Period	Supplier	O	T	O	T	O	T
Average 6 months	Boston	**15.2%**	15.6%	**4.0**	3.8	**65.8%**	67.6%
	Cook	**11.3%**	13.3%	**4.3**	3.6	**58.6%**	61.5%
	Others	**3.5%**	2.0%	**1.6**	2.9	**64.3%**	42.2%
	Average Supplier	**10.0%**	10.3%	**3.3**	3.4	**62.9%**	57.1%
	Correlation, *r*	0.98		0.95		-0.09	
	Mean Absolute Deviation	1.3%		0.7		8.9%	
First 6 months	Boston	**12.5%**	14.8%	**4.3**	3.6	**76.8%**	80.2%
	Cook	**7.5%**	6.8%	**2.7**	2.9	**80.0%**	56.5%
	Others	**2.5%**	1.4%	**1.5**	2.6	**100.0%**	47.0%
	Average Supplier	**7.5%**	7.7%	**2.8**	3.1	**85.6%**	61.2%
	Correlation, *r*	0.99		0.99		-0.80	
	Mean Absolute Deviation	1.4%		0.7		26.6%	

Table 6.4 Dirichlet predictions (3 year)

		Penetration		Purchase Frequency		SCR	
Base Period	Supplier	O	T	O	T	O	T
Average 6 months	Boston	**37.5%**	27.2%	**9.7**	13.3	**58.2%**	59.5%
	Cook	**35.0%**	24.0%	**8.3**	12.2	**48.9%**	51.9%
	Others	**10.0%**	4.2%	**3.5**	8.3	**44.4%**	28.8%
	Average Supplier	**56.2%**	18.5%	**12.2**	11.3	**50.5%**	46.7%
	Correlation, *r*	1.00		1.00		0.89	
	Mean Absolute Deviation	9.0%		4.1		6.6%	
First 6 months	Boston	**37.5%**	25.9%	**9.7**	12.5	**58.2%**	74.0%
	Cook	**35.0%**	13.5%	**8.3**	8.9	**48.9%**	43.6%
	Others	**10.0%**	3.1%	**3.5**	7.3	**44.4%**	32.1%
	Average Supplier	**56.2%**	14.2%	**12.2**	9.5	**50.5%**	49.9%
	Correlation, *r*	0.88		0.87		1.00	
	Mean Absolute Deviation	13.3%		2.4		11.1%	

Table 6.3 presents the predictions for a six month period and Table 6.4 the predicted behaviours for the 36 month period. It can be seen from the

correlations and the Mean Absolute Deviation that there is an approximate fit between the observed data and the predictions for both base periods for penetration and purchase frequency although not for share of category requirements. In both cases the fit deteriorates when the predictions are extended to 36 months although the average six months does a better job of predicting behaviours over this period as it captures the growth in the penetration for Cook. This analysis confirms the observation from the charts that there is a clear trend in Cook's market position. The initial conditions (first six months) provide less good predictions of three year performance than the averaged conditions, demonstrating that there are changes in behaviour over the three years. Cross sectional analysis of shorter time periods within the data set will allow analysis of the way in which the market structure has developed.

6.2.3 Summary Statistics

Table 6.5 a-c shows the summary statistics for 2006, 2007 and 2008. The total purchases differ slightly from those shown in Table 6.2 because the "year" in Table 6.5 (and Table 6.1) is taken to be 48 weeks (12 equal 4 week periods) rather than calendar months.

The tables show the progression in Cook market share and purchase frequency and the typical Dirichlet patterns of a wide range in market share and penetration across the five suppliers but much less variation in purchase frequency. However, the patterns of Double Jeopardy are quite marked where the low share suppliers (Rocket, Bard and Euromedical) not only have fewer buyers but also a much lower frequency of purchase than the two dominant suppliers.

Table 6.5 Summary statistics 2006 - 2008

(a) 48 weeks 2006 Summary Statistics

	Total 12 Months (2006)				
Supplier	Number of Purchases	Number of Buyers	Purchase Frequency	Penetration (%)	Market Share (%)
Boston	99	15	6.6	37.5%	70.7%
Cook	34	10	3.4	25.0%	24.3%
Rocket	4	1	4	2.5%	2.9%
Bard	3	1	3	2.5%	2.1%
Euromedical	0	0	0	0.0%	0.0%
Total	140	20	7	50.0%	

(b) 48 weeks 2007 Summary Statistics

	Total 12 Months (2007)				
Supplier	Number of Purchases	Number of Buyers	Purchase Frequency	Penetration (%)	Market Share (%)
Boston	121	21	5.8	52.5%	51.3%
Cook	100	13	7.7	32.5%	42.4%
Rocket	3	2	1.5	5.0%	1.3%
Bard	6	4	1.5	10.0%	2.5%
Euromedical	6	2	3.0	5.0%	2.5%
Total	236	29	8.1	72.5%	

(c) 48 weeks 2008 Summary Statistics

	Total 12 Months (2008)				
Supplier	Number of Purchases	Number of Buyers	Purchase Frequency	Penetration	Market Share
Boston	68	11	6.2	27.5%	38.0%
Cook	105	15	7.0	37.5%	58.7%
Rocket	5	2	2.5	5.0%	2.8%
Bard	1	1	1.0	2.5%	0.6%
Euromedical	0			0.0%	0.0%
Total	179	20	9.0	50.0%	

6.3 Data Analysis and Interpretation

6.3.1 Sample Frame

As has been noted in the previous section, there is some year to year variability in both market share and purchase frequency for particular brands, and some movement in the purchasing population. To accommodate this variability, the model is parameterised using a 12 week period from each year and tested for goodness of fit against this period and a contiguous, successive 12 week period. The sample and test periods are taken from times when the market shares of the main suppliers are relatively stable. The sample periods and their corresponding hold-out samples are 2006, weeks 13 to 24 and weeks 25 to 36, 2007, weeks 25

to 36 and weeks 37 to 48 (weeks 77 to 88 and 89 to 100 in the full three year data set) and 2008, weeks 13 to 24 and weeks 25 to 36 (weeks 117 to 128 and 129 to 140 in the three year data set). Loyalty performance measures (share of category requirements) are also compared across the three year period.

6.3.2 Purchase Distributions

The purchase distributions (i.e. proportion of purchasers making 0, 1, 2, 3, … purchases in the time period) predicted by the NBD are compared to the observed distributions. A simple correlation test is used to assess the fit between the predicted distribution and the observed distributions for both the base period (i.e. the period used to fit the distribution) and the hold-out period.

Table 6.6 Comparison between observed and predicted distribution of purchases

		Correlation between observed and theoretical distributions (r)		Mean Absolute Deviation between observed and theoretical distributions		Observed distribution
Year	Supplier	Base Period	Hold-out Period	Base Period	Hold-out Period	Standard Deviation
2006	Boston	0.94	0.96	4.2	4.8	18.6
	Cook	0.93	0.83	6.2	7.1	26.7
	Others	0.98	0.98	4.6	4.6	33.3
	Any	0.97	0.96	4.5	3.8	19.6
2007	Boston	0.87	0.94	5.7	4.1	15.6
	Cook	0.80	0.81	8.0	7.7	15.9
	Others	0.97	0.97	6.3	6.3	33.3
	Any	0.96	0.96	3.6	4.7	13.3
2008	Boston	0.40	0.88	13.5	6.4	16.7
	Cook	0.86	0.88	10.4	6.1	24.6
	Others	0.99	0.99	2.7	2.7	33.3
	Any	0.85	0.91	9.7	4.6	22.6

The strength of the correlations is high in all cases except Boston in 2008. In 15 of the 24 cases (62.5%) the correlation coefficient, *r*, is higher than the benchmark correlation coefficient of 0.9 and in 23 of the 24 cases (96%) *r* is higher than 0.8 (Table 6.6). The mean absolute deviation (MAD) is also

presented in the table and in all cases the MAD is small compared to the standard deviation of the observed distribution. The NBD is able to describe the observed data and to predict behaviour in a subsequent period with some accuracy although as will be seen below there is a systematic tendency to underestimate light buyers and overestimate heavy buyers.

Plotting the observed and expected distributions (Figures 6.5 to 6.8) also shows a generally good fit between the model predictions and the observed data. The charts only show the observed distribution from the base period: the observed data from the hold out sample is omitted for clarity.

The plotted distribution for the category (Figure 6.8) shows that the model underestimates both the proportion of light buyers (especially once only buyers) overestimates the proportion of heavier (two purchases or more) buyers. The under-estimation of light buyers has been observed previously in the NBD and has been attributed to "never buyers" (Dunn et al, 1983). In 2007 the proportion of light buyers of Cook is overestimated. The proportion of light buyers of Boston is a close fit in 2006 and overestimated in 2008. For Cook in 2007 and Boston in 2008 the over-estimation results from the impact of a relatively small number of unusually high frequency buyers (see Table 6.7).

The underestimation of both light and heavy buyers is most marked when the purchasing population is most polarised i.e. a small number of buyers accounts for a large proportion of purchases. As can be seen from Table 6.1, the top three buyers account for approximately 60% of purchases in 2006, 50% in 2007 and 70% in 2008. The relatively small buying population also distorts the picture. In the case of Boston in 2008, the contribution of the small purchasing

population to the poor fit can be seen clearly. In this case there are only three purchasers and thus each represents 33.3% of the purchasing population. The behaviour of these three relatively high volume purchasers has an extremely distorting effect on the observed distribution.

Figures 6.5 and 6.6 also show that between 2006 and 2007 the proportion of light buyers decreased for both Boston and Cook. In 2008 the observed proportion of light buyers of Boston fell again while that for Cook returned to the 2006 level. This pattern can also be seen in the data for penetration and purchase frequency and will be discussed further in the next section.

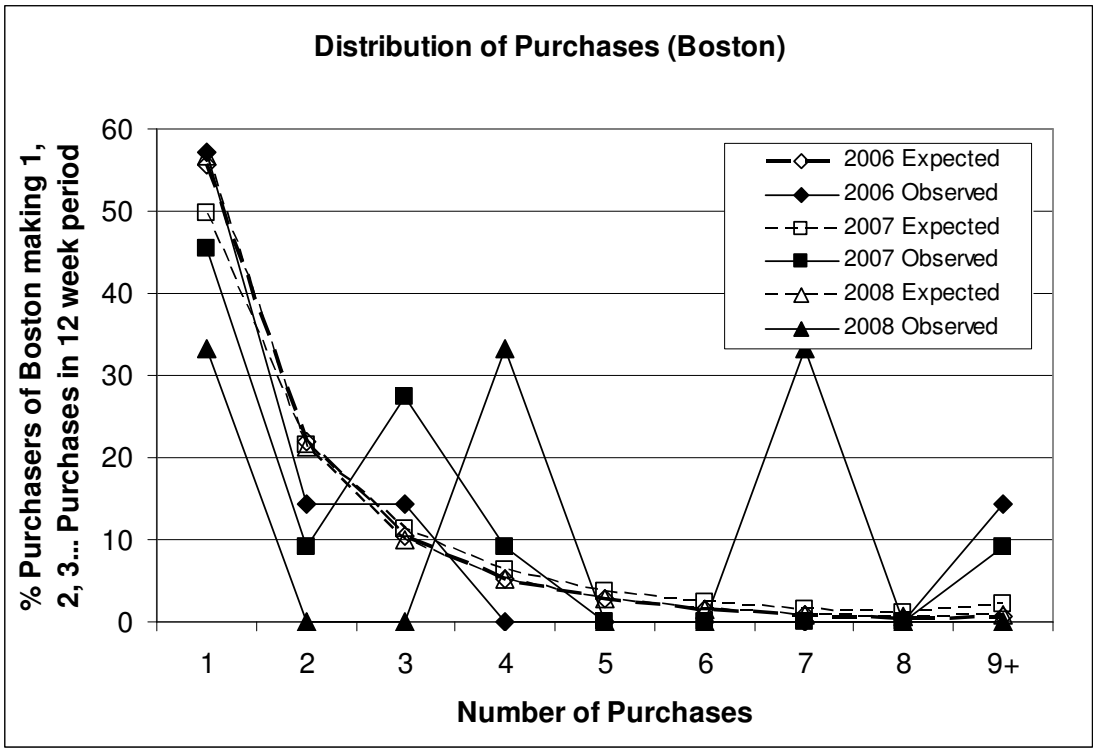

Figure 6.5 Expected and observed distribution of purchases (Boston) 2006 – 2008

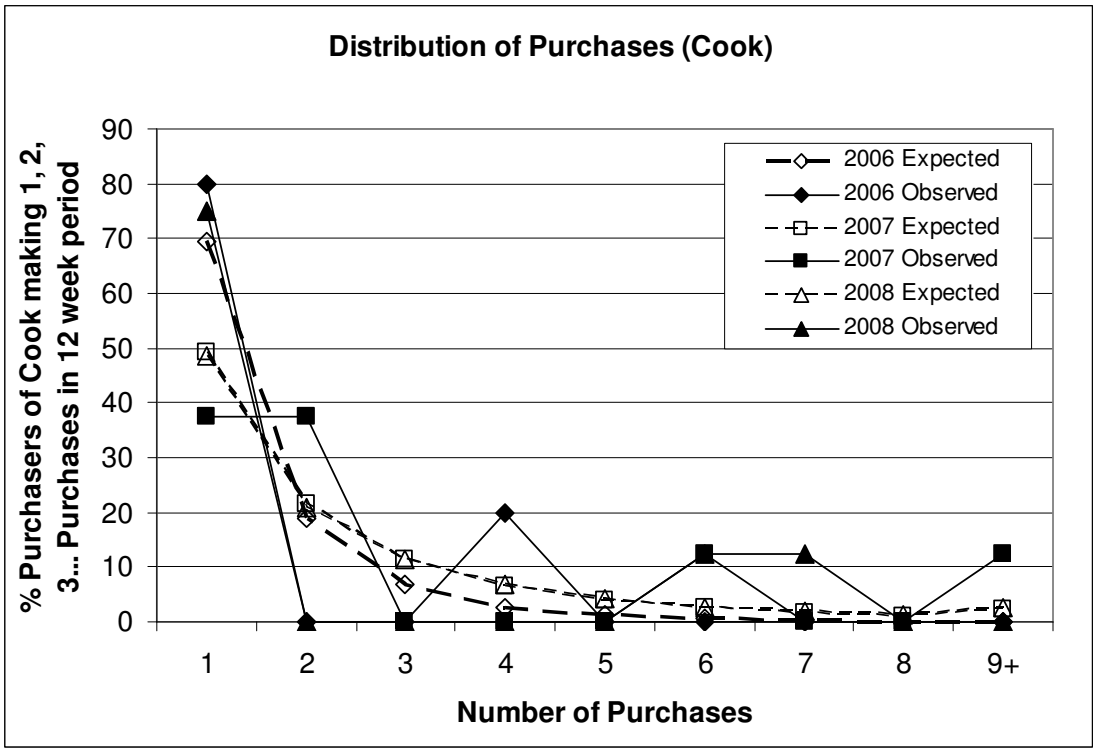

Figure 6.6 **Expected and observed distribution of purchases (Cook) 2006 – 2008**

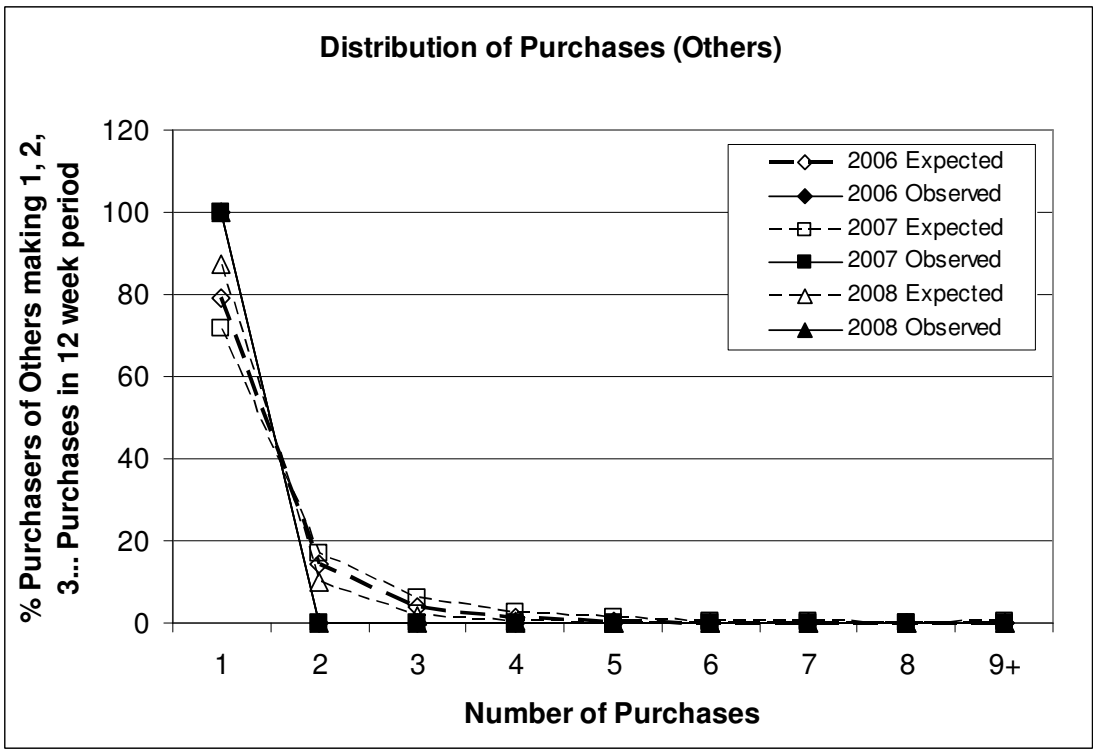

Figure 6.7 **Expected and observed distribution of purchases (Others) 2006 – 2008**

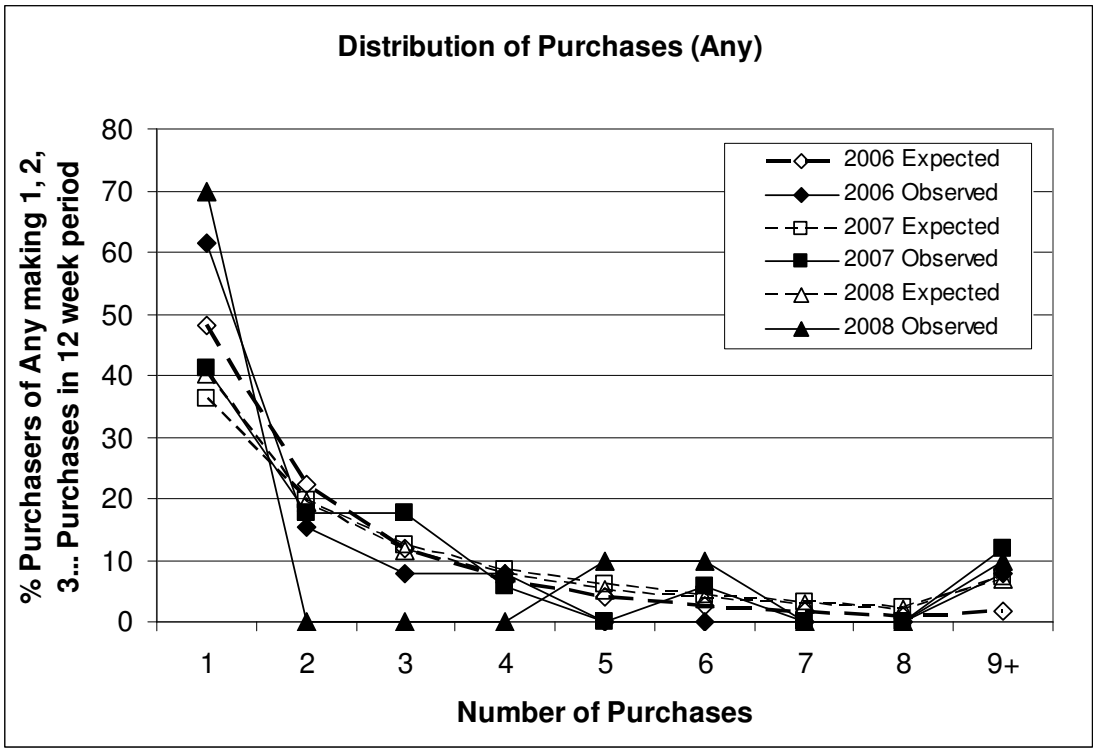

Figure 6.8 **Expected and observed distribution of purchases for product category (Any) 2006 – 2008**

6.3.3 Penetration Growth

Table 6.7 presents the observed and expected 12 week penetration rates and purchase frequencies for each supplier over the three years. It can be seen that the penetrations for both Boston and Cook change markedly across the three years as Cook improves its market position to become the market leader. The decline in Boston's share of the market is clearly linked to a reduction in the number of purchasers – fewer buyers are choosing Boston in 2008 compared to 2007 and 2006. There is a corresponding increase in the share of the purchasing population that choose Cook in 2007 and 2008. Between 2006 and 2007 the number of purchasers (in the base period) increased from 13 to 17, resulting in a general increase in penetration for the category that is reflected across all the suppliers. However in the base period in 2008 the number of purchasers

dropped back to 10. Cook kept the purchasers gained in 2007 (12 week penetration 20%) while Boston lost purchasers and hence market share.

Table 6.7 Observed and theoretical performance measures (12 week analysis period)

		Penetration		Purchase Frequency	
Year	Supplier	**O**	T	**O**	T
2006	Boston	**17.5%**	25.6%	**2.9**	1.9
	Cook	**12.5%**	13.1%	**1.6**	1.5
	Others	**5.0%**	3.8%	**1.0**	1.3
	Average Supplier	**11.7%**	14.2%	**1.8**	1.6
	Correlation, *r*	0.98		1.00	
	Mean Absolute Deviation	3.3%		0.5	
2007	Boston	**30.0%**	30.5%	**2.3**	2.3
	Cook	**15.0%**	31.1%	**4.8**	2.3
	Others	**7.5%**	5.0%	**1.0**	1.5
	Average Supplier	**17.5%**	22.2%	**2.7**	2.0
	Correlation, *r*	0.74		0.76	
	Mean Absolute Deviation	6.4%		1.0	
2008	Boston	**7.5%**	15.4%	**4.0**	1.9
	Cook	**20.0%**	19.8%	**2.4**	2.4
	Others	**2.5%**	2.2%	**1.0**	1.2
	Average Supplier	**10.0%**	12.4%	**2.5**	1.8
	Correlation, *r*	0.87		0.55	
	Mean Absolute Deviation	2.8%		0.8	

Buyers of Boston continue to purchase at roughly the same frequency through the three years although there is an increase in 2008 as purchases of Boston are consolidated into a smaller number of heavier purchasers. The purchase frequency for Cook increases sharply in 2007 before falling back in 2008.

A comparison of the observed (O) and theoretical (T) penetrations and purchase frequencies shows that there are some deviations from the NBD-Dirichlet

model. In 2007 and 2008 the correlation coefficients are lower than the 0.9 benchmark. In 2007 the Mean Absolute Deviation between observed and theoretical penetration rates is also large compared to the performance in 2006 and 2008. In all cases where there are deviations these tend to overestimate the penetration (i.e. the number of buyers) and underestimate the purchase frequency. These deviations arise because the purchasing population is partitioned into a "heavy" segment with a few high frequency buyers and a "light" segment with the remainder of buyers.

Table 6.8 Observed and theoretical performance measures, heavy purchasers (12 week analysis period)

		Penetration		Purchase Frequency	
Year	Supplier	**O**	T	**O**	T
2006	Boston	**5.0%**	6.0%	**6.5**	5.4
	Cook	**2.5%**	2.0%	**4**	4.9
	Others	**0.0%**	0.0%	**0.0**	0.0
	Average Supplier	**3.8%**	4.0%	**5.3**	5.1
	Correlation, *r*	0.98		0.95	
	Mean Absolute Deviation	0.5%		0.7	
2007	Boston	**5.0%**	5.5%	**6.0**	5.3
	Cook	**7.5%**	6.7%	**7.3**	8.1
	Others	**0.0%**	0.0%	**0.0**	0.0
	Average Supplier	**6.3%**	6.1%	**6.7**	6.7
	Correlation, *r*	0.99		0.98	
	Mean Absolute Deviation	0.4%		0.5	
2008	Boston	**5.0%**	5.8%	**5.5**	4.7
	Cook	**7.5%**	6.3%	**4.7**	5.5
	Others	**0.0%**	0.0%	**0.0**	0
	Average Supplier	**6.3%**	6.0%	**5.1**	5.1
	Correlation, *r*	0.97		0.96	
	Mean Absolute Deviation	0.7%		0.5	

Tables 6.8 and 6.9 show the expected 12 week penetration rates for a "heavy" segment (containing the three cost centres with the highest number of purchases) and a "light" segment containing the remainder of the purchasing cost centres.

Table 6.9 Observed and theoretical performance measures, light purchasers (12 week analysis period)

		Penetration		Purchase Frequency	
Year	Supplier	**O**	T	**O**	T
2006	Boston	**12.5%**	15.0%	**1.4**	1.2
	Cook	**10.0%**	9.1%	**1.0**	1.1
	Others	**5.0%**	4.8%	**1.0**	1.0
	Average Supplier	**9.2%**	9.7%	**1.1**	1.1
	Correlation, *r*	0.96		0.87	
	Mean Absolute Deviation	1.2%		0.1	
2007	Boston	**25.0%**	27.0%	**1.6**	1.5
	Cook	**7.5%**	13.8%	**2.3**	1.3
	Others	**7.5%**	6.4%	**1.0**	1.2
	Average Supplier	**13.3%**	15.7%	**1.6**	1.3
	Correlation, *r*	0.94		0.29	
	Mean Absolute Deviation	3.1%		0.4	
2008	Boston	**2.0%**		**1.0**	
	Cook	**10.0%**		**1.0**	
	Others	**2.0%**		**1.0**	
	Average Supplier	**4.7%**		**1.0**	
	Correlation, *r*				
	Mean Absolute Deviation				

The NBD-Dirichlet describes penetration rates and purchase frequency for the heavy purchasers with good accuracy as assessed by both the correlation coefficient and the Mean Absolute Deviation (Table 6.8). The fit for the light segment is less good (Table 6.9). It has not been possible to fit the model for the

2008 data (seven purchasers, each making a single purchase) but the observed measures are presented in Table 6.9.

Table 6.8 shows that in the heavy purchasing segment there is little change in Boston's performance over the three years but that Cook gains buyers (from one of the heavy buyers in 2006 to all three in 2007 and 2008). The largest deviation in the light purchasing segment occurs for Cook in 2007 where the penetration is overestimated and the purchase frequency underestimated. There is a general reduction in the number of purchasers in the light segment, perhaps as a result of some buyer consolidation, and a notable collapse in the number of Boston purchasers from a penetration of 25% (10 purchasers) to 2.5% (1 purchaser).

6.3.4 Share of Category Requirements

Share of Category Requirements (SCR) is a widely used loyalty measure and is one of the outputs of the NBD-Dirichlet model. As well as providing an assessment of the fit of the model, the trends in SCR provide some insights into the changes in market position taking place over the three year time period.

Table 6.10 shows the observed and theoretical SCR for Boston, Cook and the aggregated Others for the entire purchasing population and the heavy and light segments as defined in the previous section. The SCR for Others is overstated because of the effect of aggregating three small suppliers into one and because the overall purchase frequencies for buyers of Others tend to be very low, giving few opportunities to satisfy requirements from alternative suppliers. This aggregated supplier accounts for less than 10% of overall purchases and will not be discussed further.

It can be seen that the fit for the entire population is not good with the correlation coefficient less than 0.9 in 2006 and 2007 and large deviations in all cases, although this is somewhat distorted by the Others data. All but one of the deviations is in the same direction, suggesting a systematic bias towards underestimating loyalty.

Such deviations from the Dirichlet benchmarks have been described in the literature (Fader & Schmittlein, 1993; Bhattacharya, 1997) as "excess behavioural loyalty". This excess loyalty has been noted as a systematic deviation from the Dirichlet model, in particular for market leading brands and as a result has been identified as a market share premium. In this case however, all suppliers (with the exception of Cook in 2008) have the loyalty premium. Fader & Schmittlein (1993) attributed such deviations to underlying segmentation of the market place with particular reference to brand availability. In the current case, such segmentation may be related to purchase frequency (heavy and light buyers) or constraints on availability. These constraints may be organisational (cost of evaluating new vendors or perceived absence of choice (Jarvis & Wilcox, 1977)), habitual (we've always bought from this supplier), policy related (a sole supply agreement) or distribution related (the sales rep stops calling because he never makes any sales). Table 6.10 shows a good fit for the heavy purchasers and a less good fit for the light purchasers.

Loyalty measures for light purchasers are affected by the opportunity that light purchasers have to repurchase (Stern & Hammond, 2004). In 2006 only one purchaser makes more than one purchase, in 2007 five buyers make more than one purchase and in 2008 no buyers make more than one purchase. Stern and

Hammond (2004) also note that loyalty measures such as SCR are dependent on the number of purchases used to calculate the measures. They observe that SCR declines sharply between 5 and 15 purchases, declines more slowly from 15 to 60 purchases after which it changes very little. Even the heaviest purchasers in the current sample only occasionally exceed 15 purchases in the analysis period.

Table 6.10 Share of Category Requirements

		Entire population		Heavy Segment		Light Segment	
Year	Supplier	**O**	T	**O**	T	O	T
2006	Boston	**95.2%**	76.4%	**100.0%**	93.4%	**87.5%**	82.4%
	Cook	**88.9%**	51.1%	**100.0%**	79.9%	**80.0%**	74.1%
	Others	**100.0%**	40.2%	**0.0%**	0.0%	**100.0%**	68.9%
	Average Supplier	**94.7%**	55.9%	**100.0%**	86.7%	**89.2%**	75.1%
	Correlation, *r*	-0.22		0.99		-0.51	
	Mean Absolute Deviation	38.8%		8.9%		14.0%	
2007	Boston	**69.0%**	58.2%	**42.9%**	36.9%	**100.0%**	77.5%
	Cook	**69.0%**	58.0%	**64.7%**	65.6%	**87.5%**	59.5%
	Others	**42.9%**	29.5%	**0.0%**	0.0%	**42.9%**	52.3%
	Average Supplier	**58.5%**	48.3%	**53.8%**	51.2%	**76.8%**	63.1%
	Correlation, *r*	1.00		0.99		0.85	
	Mean Absolute Deviation	11.7%		2.3%		20.0%	
2008	Boston	**60.0%**	46.6%	**57.9%**	46.1%	**100.0%**	
	Cook	**63.3%**	65.0%	**56.0%**	57.6%	**100.0%**	
	Others	**100.0%**	19.5%	**0.0%**	0.0%	**100.0%**	
	Average Supplier	**74.4%**	43.7%	**56.9%**	51.9%	**100.0%**	
	Correlation, *r*	-0.88		0.98			
	Mean Absolute Deviation	31.9%		4.5%			

Several patterns can be identified from the SCR measures. The heavy purchasers generally exhibit lower loyalty levels than light purchasers. This is to be expected as the heavier purchasers have more opportunities to change supplier. Over the three years of the analysis the observed and predicted loyalty levels decline as the heavy (and initially extremely loyal) purchasers of Boston add Cook to their purchasing repertoire. In 2007 and 2008 the measures

approach the Dirichlet norms. By 2008 Cook's excess behavioural loyalty has been eliminated although Boston still enjoys a small premium.

6.3.5 Duplication of Purchases

Analysis of the other suppliers purchased by buyers of a particular supplier can be useful to identify clustering of particular suppliers or to identify potential substitute suppliers to facilitate supplier development or supplier rationalisation initiatives. In this case with only two dominant suppliers the analysis is perhaps a little artificial in that if purchasers of Boston do buy from another supplier, it is quite likely that the other supplier will be Cook. This expected pattern of behaviour is indeed observed as can be seen in Table 6.11. There is little duplication of purchase between Others and either Boston or Cook reflecting the low number of purchasers of Others.

The way in which the duplication of purchase develops through the three years shows that buyers of Boston become more likely to buy also from Cook. In 2006 only 14.3% of Boston buyers buy from Cook. By 2008 this percentage has increased to 66.7%. Over the same period, the same analysis for Cook shows that the percentage of Cook buyers that also buy from Boston remains relatively steady.

Table 6.11 Observed duplication of purchase (entire buying population)

Year	First Purchase	Who also purchase from: Second Purchase		
	Buyers who purchase from:	Boston	Cook	Others
2006	Boston	-	14.3%	0.0%
	Cook	20.0%	-	0.0%
	Others	0.0%	0.0%	-
	Average observed duplication	10.0%	7.1%	0.0%
2007	Boston	-	16.7%	0.0%
	Cook	33.3%	-	16.7%
	Others	0.0%	33.3%	-
	Average observed duplication	16.7%	25.0%	8.3%
2008	Boston	-	66.7%	0.0%
	Cook	25.0%	-	0.0%
	Others	0.0%	0.0%	-
	Average observed duplication	12.5%	33.3%	0.0%

The trend for buyers of Boston to increase the extent to which they also purchase from Cook can be observed even more clearly when the duplication for the heavy purchasers is considered. It is this segment that has shown the biggest change in purchasing behaviour (see Table 6.10 in previous section) and the increased tendency towards split loyalty behaviour is also demonstrated in the duplication behaviours. Table 6.12 presents the duplication of purchase for the heavy segment. In 2006 these heavy purchasers are solely loyal – there is no duplication of purchase. However in 2007 and 2008 all buyers of Boston also buy from Cook and two thirds of buyers of Cook also buy from Boston.

Table 6.12 Observed duplication of purchase (heavy purchasing segment)

Year	First Purchase	Who also purchase from: Second Purchase		
	Buyers who purchase from:	Boston	Cook	Others
2006	Boston	-	0.0%	0.0%
	Cook	0.0%	-	0.0%
	Others	0.0%	0.0%	-
	Average observed duplication	0.0%	0.0%	0.0%
2007	Boston	-	100.0%	0.0%
	Cook	66.7%	-	0.0%
	Others	0.0%	0.0%	-
	Average observed duplication	66.7%	100.0%	0.0%
2008	Boston	-	100.0%	0.0%
	Cook	66.7%	-	0.0%
	Others	0.0%	0.0%	-
	Average observed duplication	66.7%	100.0%	0.0%

6.4 Discussion

The preceding empirical analysis has shown that the reported purchasing behaviour can be satisfactorily modelled using the NBD-Dirichlet. Although the fit is generally good, some systematic deviations from the model behaviour are observed. These deviations may arise from sampling errors introduced by the relatively small number of purchasers or errors and omissions in the data set (Ehrenberg, 1988). Deviations will also occur as a result of violation of the Dirichlet assumptions of stationarity, lack of partitioning and the independence of supplier choice and purchase incidence (Sharp & Driesener, 2000).

No detailed qualitative analysis was conducted as the ureteral stent category had not been subject to any procurement intervention. However, the ureteral stent

case was raised during the interviews with purchasing executive at the collaborative procurement hub. The Deputy Director of Procurement confirmed that the ureteral stent category had not been the subject of any procurement intervention and that the change in market structure appears to have been the result of an aggressive and targeted promotional campaign by Cook. As the Deputy Director commented during the interview, "*They've certainly been busy over the last few years. They've invested a hell of a lot in their sales force in the region.*"

6.4.1 Dirichlet Assumptions

Although the largest purchasers of the category have relatively stable purchasing rates, their supplier choices change through the three year analysis period. There is also a large amount of churn in the remainder of the buying population with buyers becoming inactive or active. The Dirichlet is a steady state model and is based on the assumption of stationary markets. As the behaviour over the three year analysis period is non-stationary, the time periods for analysis have been chosen to give approximately stable purchasing behaviour for the cross sectional analysis. As can be seen from the comparison between time periods in the longitudinal analysis, there are major differences between the behaviours in these periods.

The second assumption that underpins the Dirichlet analysis is that the market is non-partitioned. The analysis has shown that segments based on purchase frequency (heavy and light purchasers) can be identified and that operationalising the model using these segments leads to an improved fit between the model predictions and observed behaviour. This may be a

statistical effect related to the number of purchases used to operationalise the model (Stern & Hammond, 2004) or the impact of the restricted repertoire exhibited by the heavy purchasers. Heavy buyers may be more likely to standardise or to have preferred supply agreements that constrain choice and hence availability of particular suppliers. The distorting impact of a small number of high frequency buyers has been noted before (Bowman & Lele-Pingle, 1997) and may be a feature of organisational markets. The heavy purchasers in this case are all acute hospital trusts with specialist urology centres. In addition, the heaviest buyer, and the trust in which the largest change in buying behaviour has been observed (100% loyal to Boston in 2006, purchases split equally between Cook and Boston in 2008), is a teaching hospital and potentially more open to alternative suppliers.

The ureteral stents case shows a successful intervention to develop a supplier as an alternative to a dominant supplier. Although this results from the actions of a supplier the analysis of this case points to several important implications for the theory and practice of organisational purchase behaviour.

6.4.2 Theoretical Implications

The analysis of the ureteral stent case represents a substantial extension of the NBD-Dirichlet model into a complex collaborative public procurement environment. Although the case describes a supplier intervention, the analysis shows how the understanding of buyer behaviour provided by the model adds to the theory of collaborative purchasing.

6.4.2.1 Extension and Replication of the NBD-Dirichlet Empirical Generalisation

The ureteral stent case is a differentiated replication of the NBD-Dirichlet model carried out to determine to what extent the model is generalisable to a new set of conditions (Lindsay & Ehrenberg, 1993), in this case the procurement of surgical supplies in a collaborative public procurement organisation. The fit of the expected behaviours predicted by the NBD-Dirichlet model with the observed purchasing behaviour patterns have been shown to satisfy the test of "stochastic sameness" (Ehrenberg & Bound, 1993). The specific conditions of the case, in particular organisational purchasing, public procurement, collaborative purchasing and expert purchasing where the choice is not made by the consumer represent a highly differentiated replication of the model.

The patterns of purchasing behaviour are typical of Dirichlet markets, with the larger suppliers having much higher market share and penetration than the smaller suppliers while the purchase frequencies for each supplier are similar, except for the Double Jeopardy effect where the smaller suppliers are purchased slightly less frequently (Ehrenberg, 1988).

The initial loyalty behaviours in the ureteral stent case are typical of a Dirichlet subscription market (Sharp et al, 2002) where buyers of a particular supplier tend to be solely loyal to that supplier. However by the end of the three year analysis period the patterns are much more like a repertoire market (Sharp et al, 2002). This is to be expected as buyers become more experienced with the alternative supplier to the point where it becomes established in the buyers' purchase portfolios.

Systematic deviations from the model predictions are observed, including a tendency to overestimate the number of buyers (penetration) and to underestimate purchase frequency and share of category requirements. These deviations result from a violation of the Dirichlet assumption of lack of partitioning (Sharp & Driesener, 2000) with a segment of high frequency buyers dominating the observed purchase behaviours. This concentration of high frequency buyers has also been noted in the analysis of foreign exchange services (Bowman & Lele-Pingle, 1997) and may be a repeatable characteristic of organisation markets.

6.4.2.2 Application of the NBD-Dirichlet Model to Collaborative Purchasing

The collaborative purchasing literature focuses on the mechanisms by which purchasing consortia arise, the development of purchasing groups and their governance (Schotanus & Telgen, 2007). There has been little research into the actual buying behaviours of organisations within purchasing consortia. The application of the Dirichlet in a collaborative purchasing context provides a coherent theory of purchasing behaviour to describe, predict and explain buyer behaviour in purchasing consortia.

One of the underlying Dirichlet assumptions is that of the repertoire of suppliers from which a buyer chooses with a steady and predictable probability each time a purchase is made. The ureteral stent case shows how the concept of the purchasing portfolio or repertoire is an important basis for analysing and understanding purchasing interventions associated with standardisation or rationalisation. Supplier development can be understood as an extension to the

buyer's repertoire, as evidenced by the performance of Cook over the analysis period. Although a stationary model, the NBD-Dirichlet can be applied over a series of time periods to allow analysis of dynamic developments in market structure as a result of such purchasing interventions.

The ureteral stent case also demonstrates how the model provides a baseline for interpretation of observed loyalty. Deviations from the Dirichlet norms can be used as a point of departure for further investigation such as the identification of distinct heavy and light purchasing segments within the buying population. The observed behaviours show a marked deviation from the expected patterns, in particular the constrained choice sets of the heavy buying segment. This group would be expected to have more opportunity to try alternative suppliers and be better informed about the supplier choices available to them than the lighter buyers. Thus the heaviest purchasers would have the greatest opportunity to use the smaller suppliers and the lightest purchasers would be more likely to use the dominant suppliers, the Natural Monopoly Phenomenon (McPhee, 1963). This deviation appears to be due to preferred supply agreements constraining supplier choice and is likely to be replicated in other purchasing environments characterised by framework agreements.

6.4.3 Managerial Implications

The theoretical predictions of the NBD-Dirichlet model provide norms and benchmarks against which to assess current behaviours and to monitor the impact of managerial interventions (Ehrenberg & Sharp, 2000). The implications of the model for managers in collaborative procurement organisations are discussed below.

6.4.3.1 Buyer Repertoires

Experienced buyers in Dirichlet markets typically purchase from a repertoire of several suppliers with steady long term purchase frequencies and fixed supplier choice probabilities (Goodhardt et al, 1984). Purchasing managers who wish to introduce a new supplier or develop an existing supplier to improve competition and increase leverage over the supply base need the new supplier to become established in buyer repertoires so that the supplier attracts more buyers (Ehrenberg, 1988) and the buyers develop enough experience with the new supplier for the choice to become routinised. The ureteral stent case provides a good illustration of the impact of a sustained supplier development effort, albeit an effort initiated by the supplier itself. Between 2006 and 2008 Cook grows its market share from 24% to 59% by increasing penetration (the number of buyers) from 25% to 37.5%. By 2008 Cook is established in the majority of buyer repertoires.

The ureteral stent case also demonstrates that interventions to change the distribution of purchases must focus on changing the number of buyers for a particular supplier (i.e. the penetration), rather than the frequency of purchase of particular suppliers. Between 2006 and 2007, Cook gained customers and saw an increase in purchase frequency, primarily because the customers gained wre high frequency purchasers. From 2007 to 2008, Cook's purchase frequency returned to a level close to the long term average as more new (low purchase frequency) customers bought from Cook. Similar conclusions have been drawn from the consumer marketing field where market share and sales increases have been shown to come from gaining new buyers, not from increased purchase frequency from existing buyers (Goodhardt et al, 1984). Experience from

consumer marketing also suggests that consumer behaviour often returns to long run average behaviour after a short term promotion (Ehrenberg, 1994). The change in Cook's position in the ureteral stent case has been achieved over a sustained period and appears to be a permanent adjustment. Further monitoring would indicate whether the new purchasing patterns are sustained.

6.4.3.2 Supplier Loyalty

The loyalty shown to particular suppliers in a competitive Dirichlet market tends to be similar across all suppliers. Buyers appear to welcome variety and choice (Ehrenberg et al, 2004), an observation noted in the collaborative hub coronary stent case. This persistent split-loyalty behaviour typical of Dirichlet markets is advantageous to purchasing managers seeking to encourage competition and choice in a particular category. The assumption of as-if random purchasing behaviours where loyalty is split between suppliers in a purchasing repertoire has implications for purchasing managers seeking to make interventions to change the purchasing behaviours of members of the purchasing group.

The ureteral stent case demonstrates the development of such split-loyalty behaviours. The conditions in the ureteral stent case show high levels of sole loyalty (Table 6.10) at the start of the analysis period such that buyers satisfy most of their requirements from a single supplier. By the end of the analysis period the ureteral stent buyers have gained experience of an alternative supplier and exhibit the split loyalty behaviours typical of a Dirichlet market. It is not clear from the data whether the initial high levels of sole loyalty result from inexperienced buyers who gain experience of Cook during the period of analysis or whether the initial position is determined by distribution effects. The

exploratory interviews suggest that the increase in Cook's market share arises from increased sales activity – the equivalent of a sustained promotional effort or securing more distribution outlets for a product. Analysis of subsequent time periods would show if Boston responds to Cook's improved performance such that the relative positions stabilise into a kind of stationary competitive equilibrium or whether the positions at the end of 2008 persist.

Excess behavioural loyalty (as measured by SCR) can be an indicator of the existence of segments where purchasing behaviours are constrained by habit, policy or availability of particular suppliers (Fader & Schmittlein, 1993). Thus comparison of observed and predicted SCR identifies such behaviours and allows the progress of any supplier development interventions to be tracked. Analysis of the purchase duplications can assist purchasing managers to identify acceptable substitute products or suppliers and form the basis of a supplier development initiative.

6.4.3.3 Dirichlet Predictions

The Dirichlet model provides theoretical norms and benchmarks that can be used to assess patterns of behaviour. It can also be used for scenario planning, for example to model the introduction of a new supplier, the development of an existing supplier or the removal of an existing supplier. As seen in the analysis of the longitudinal ureteral stent data the Dirichlet can also be used to analyse dynamic market development over an extended period (Ehrenberg et al, 2004).

In 2006, buyers of Boston and Cook satisfy approximately 90% of their category requirements from a single supplier, a purchasing pattern that is more like a subscription market than a competitive split loyalty repertoire market (Sharp et

al, 2002). These high observed loyalties suggest an opportunity for intervention to expand the buyers' repertoires beyond their single preferred supplier perhaps by building increased awareness of credible alternatives or increased transparency in pricing. By 2008, after a sustained promotional intervention by Cook, the share of category requirements was less than 60% for each supplier.

The Dirichlet predictions can also be used by purchasing managers to simulate changes in market structure like those observed in the ureteral stent case. This is discussed further in Section 8.3.3.3 where the change in Cook's market share from 24% in 2006 to 59% in 2008 is simulated, demonstrating the effect of this change on penetration, purchase frequency and share of category requirements.

6.5 Summary

This chapter has presented the analysis of ureteral stent purchasing data from three full years (April 2006 to March 2008) for reporting trusts in the Collaborative Purchasing Hub (CPH). Although the period of analysis covers a three year period during which sustained supplier activity results in a change to the market structure with an initially dominant incumbent supplier losing market position, it has been shown that the observed purchasing behaviours and the dynamics of these changing behaviours can be described by the NBD-Dirichlet.

The analysis of the ureteral stent case is a substantial replication and extension of the NBD-Dirichlet into a collaborative public procurement purchasing environment, adding to the Dirichlet literature and a novel contribution to the collaborative purchasing literature. The case also demonstrates how the NBD Dirichlet can provide benchmarks against which observed behaviours can be

assessed. The longitudinal analysis shows how such benchmarks can be used to identify targets for purchasing management supply side or demand side interventions, to suggest strategies for intervention and to track the progress of such interventions.

The next chapter develops the contribution of the Dirichlet to describing, predicting and explaining buying behaviour in collaborative purchasing organisations. It considers the case of coronary stents in the collaborative procurement hub, a category that has been subject to purchasing management intervention in the form of a set of supplier framework agreements. The purchase behaviours before and after the implementation of the frameworks are analysed to demonstrate the impact of the intervention and the application of the Dirichlet in tracking the resulting changes in buying behaviour.

7 Modelling Coronary Stent Procurement in a Collaborative Purchasing Hub

7.1 Introduction

Coronary stents represent the second largest stent category in the collaborative procurement hub by number of purchase occasions. The category has also been a target for a major purchasing intervention and the 2006 – 2008 data set covers the run up to the implementation of a negotiated set of framework agreements in September 2008. The background to these interventions has been investigated through an exploratory interview process with representatives of the collaborative procurement hub. This has provided valuable contextual information to aid the interpretation of the observed behaviours.

The chapter proceeds with a description of the data set, followed by the operationalisation of the model and testing for goodness of fit. It is shown that the NBD-Dirichlet can provide satisfactory predictions of observed purchasing behaviour. The analysis replicates the findings of the ureteral stent case and is a further extension of the NBD-Dirichlet model into a new market structure, the collaborative public procurement environment, and into a new management discipline, purchasing and supply management.

Systematic deviations from the Dirichlet model predictions are observed and analysed. As in the ureteral stent category, the buying population can be partitioned into a high purchase frequency and a low purchase frequency segment. Other factors contributing to the observed deviations include the

presence of a single, solely loyal, high frequency purchaser whose actions dominate the analysis of observed purchasing behaviours, particularly towards the end of the analysis period when there is a smaller number of buyers.

Through the analysis period there is a marked reduction in the proportion of the buying population that make purchases, although the frequency of purchase remains relatively constant. The reduction happens in the twelve months prior to the new framework contracts being finalised and may be evidence of inventory reduction before more attractive pricing comes into force or increased purchase quantity per purchase occasion as suppliers offer deals to improve their position during the framework negotiations. Following the implementation of the framework agreements, changes to the supplier loyalty patterns are observed. This may be due to increased awareness of credible alternatives as a result of the frameworks.

The model predictions provide a useful benchmark for collaborative purchasing organisations to understand the market dynamics for a particular category and to identify opportunities for intervention, including the use of observed duplication of purchase behaviours to identify potential alternative suppliers. The very different dynamics of this case compared to the ureteral stent category further demonstrates the power of the Dirichlet as a theoretical model to understand and inform purchasing and supply management decision-making.

7.2 Description of the Data

7.2.1 Purchases by Requisitioner

During the three year period, 18 purchasers made 402 purchases of this category. This is a much smaller purchasing population than that observed for the ureteral stents and there is evidence of buyer consolidation during the observation period with 10 cost centres making purchases in 2006, 7 in 2007 and 6 in 2008. Only one cost centre is active through the entire purchasing period. This could be due to a policy of buyer consolidation, inventory reduction or deliberate under-reporting although there has been no central initiative to reduce the number of buying centres. The purchasing population has a higher proportion of heavy purchasers with over half of the cost centres (10 out of 18) who make at least one purchase during the three years making ten or more purchases. For the ureteral stents, there are also 10 cost centres making 10 or more purchases but this represents less than one quarter of the purchasing population. Consequently the tail of infrequent buyers is relatively short with 9 buyers making 5 or fewer purchases in the three years (Figure 7.1).

Excluding buyers who made only one purchase in the period and thus have no opportunity to change supplier, only a single buyer fulfilled their requirements from a single supplier throughout the period of analysis. There is consolidation in the population of buyers through the three years with the top three buyers making 66% of purchases in 2006, 74% of purchases in 2007 and 89% in 2008. The heaviest buyers show remarkable diversity in their purchasing choice sets as seen in Table 7.1.

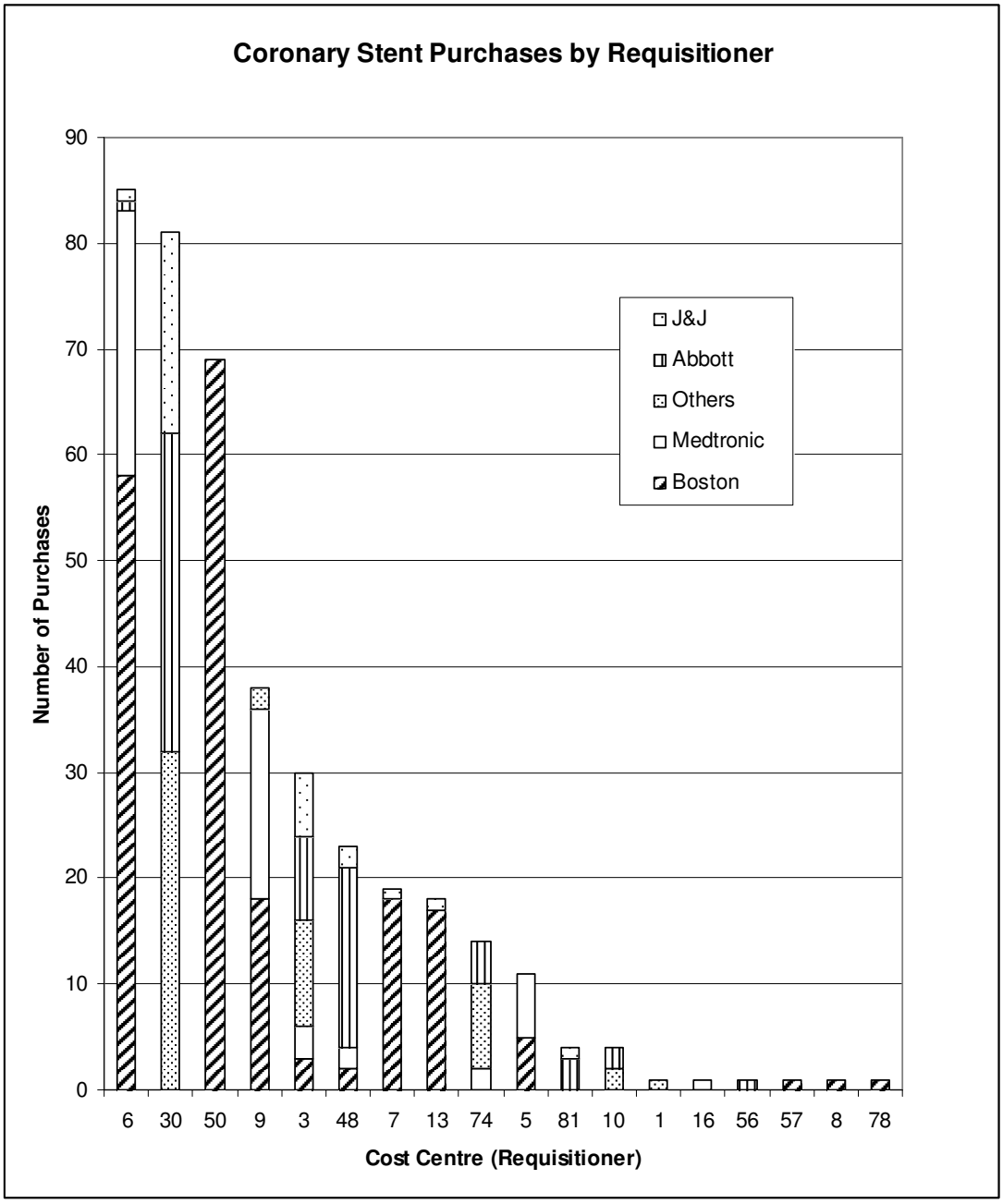

Figure 7.1 Coronary stent purchases by requisitioner

One cost centre places all of its purchases with just a single supplier (the dominant supplier in the category) while another, with a similar number of purchases, uses six suppliers (Abbott, J&J and four smaller suppliers that are aggregated into the Others supplier) over the course of the analysis. This difference does not appear to be due to demography – both trusts are acute trusts with specialist cardiology centres.

Table 7.1 Cost Centre choice sets (2006 – 2008)

Cost Centre	Number of Purchases	Number of Suppliers Used (Choice Set)
6	82	4
30	81	6
50	69	1
9	41	3
3	30	8
48	23	4
7	19	2
13	18	2
74	14	3
5	11	2
81	4	2
10	4	2
1	1	1
16	1	1
56	1	1
57	1	1
8	1	1
78	1	1

Consistent with the Natural Monopoly Phenomenon (McPhee, 1963) whereby the heaviest purchasers have the greatest opportunity to use a wide range of suppliers, this diverse purchasing behaviour contrasts with the observations from the pilot data and the ureteral stent data analyses where the heaviest purchasers show a preference for the main suppliers in the category. The implication is that there are none of the restrictions on choice sets like those seen in the single trust coronary stent case or the ureteral stent case.

7.2.1.1 Poisson Assumption

A number of observations can be made from the tabulated half year purchase frequencies for each cost centre (Table 7.2). Only one buyer makes purchases in each of the three years, and does so with a reasonably stable annual purchase frequency although the number of purchases is not evenly distributed between

the first and second halves of the year. The purchase frequency of the other buyers is generally stable through the period in which they make purchases. Thus the assumption that the purchase distribution for an individual purchaser can be described by a Poisson process is assumed to hold within these defined periods. As for the ureteral stent data, cross-sectional analysis can be carried out within a defined period or relative stability and the observations from successive years compared in the longitudinal analysis.

There is a sharp decline in overall category purchases in 2007 with a slight recovery in the second half of 2008. This decrease is due to a combination of a reduction in the number of buyers and a reduction in the number of purchases made by buyers. The new framework agreements were negotiated during 2007 and implemented in the second half of 2008. Although no specific purchasing interventions took place during 2007, the fact that purchases of the cardiac (coronary) stent category were being analysed and discussed in preparation for the framework negotiations appears to have influenced purchasing behaviours. Inventories may have been run down in anticipation of new and more advantageous pricing, purchase quantity per purchase occasion may have increased as suppliers offer attractive deals to build position during the framework negotiations or buyers may be responding to increased scrutiny of purchasing behaviour.

Table 7.2 Purchases by requisitioner (2006 – 2008)

Cost Centre	2006		2007		2008		Average
	H1	H2	H1	H2	H1	H2	
6	43	24	10	3			13.3
30	19	1	6	15	6	20	11.2
50			19	13	21	13	11.0
9					14	27	6.8
3	12	12	1	1			4.3
48	5	4	8	5			3.7
7	2	17					3.2
13	8	6					2.3
74					2	8	1.7
5						8	1.3
81			1	3			0.7
10			4				0.7
1						1	0.2
16		1					0.2
56		1					0.2
57		1					0.2
8	1						0.2
78						1	0.2
Total Purchases	90	79	49	40	43	70	61.8
Total Requisitioners	7	9	7	6	4	7	6.7

7.2.2 Purchases by Supplier

Three suppliers, Boston Scientific, Medtronic and Abbott, together account for 316 of the 402 purchase orders, equivalent to 79% of the total. A further six suppliers make up the balance. The three major suppliers are dominant throughout the three year period, although there is a dramatic decline in the Medtronic market share in 2007 (Table 7.3).

Table 7.3 shows how the reduction in purchase incidence in 2007 affects all the suppliers except Abbott. In 2008, most suppliers see a slight recovery except J&J and Biotronik. The smaller suppliers (in particular Atrium, B Braun and Terumo) increase their purchase incidence in 2008.

Table 7.3 Coronary stent purchases by supplier

Supplier	Year			TOTAL
	2006	2007	2008	
BOSTON	89	46	58	193
MEDTRONIC	23	5	29	57
ABBOTT	25	25	16	66
J&J	20	6	5	31
BIOTRONIK	14	1	0	15
ATRIUM	0	2	9	11
ORBUS	1	7	3	11
B BRAUN	2	1	6	9
TERUMOL	1	1	7	9
TOTAL	175	94	133	402

Figure 7.2 shows the monthly market share for each supplier plotted through the three year period. The approximate start of the cardiac stent project in August 2007 and the implementation of the resulting framework agreements in September 2008 are shown on the chart. Boston is the market leader through most of the period but appears to experience a drop in market share towards the end of 2008, perhaps as a result of the introduction of the framework agreements. Another feature of this plot is the period in 2007 (from about Month 16 to 22) where the market shares of suppliers other than Boston or Abbott fall to close to zero. After the implementation of the framework agreements in September 2008 the other suppliers appear to return to the market.

Analysis of the monthly purchase frequency over the same period shows a reduction in purchase frequency in 2007, followed by an increase in the second half of 2008 (Figure 7.3). The frequency of purchase of Medtronic is noteworthy, with high purchase frequency in the first few months of the analysis, very little activity through all of 2007 and a marked increase in

purchase frequency in 2008, in particular following the implementation of the framework agreement.

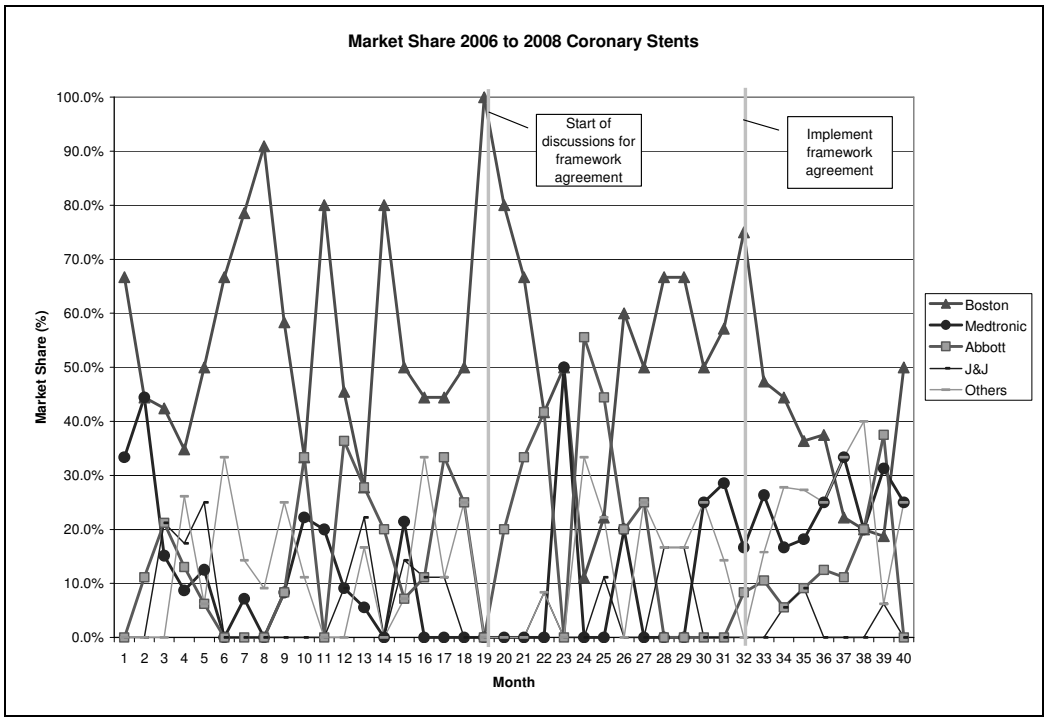

Figure 7.2 Monthly market share by supplier

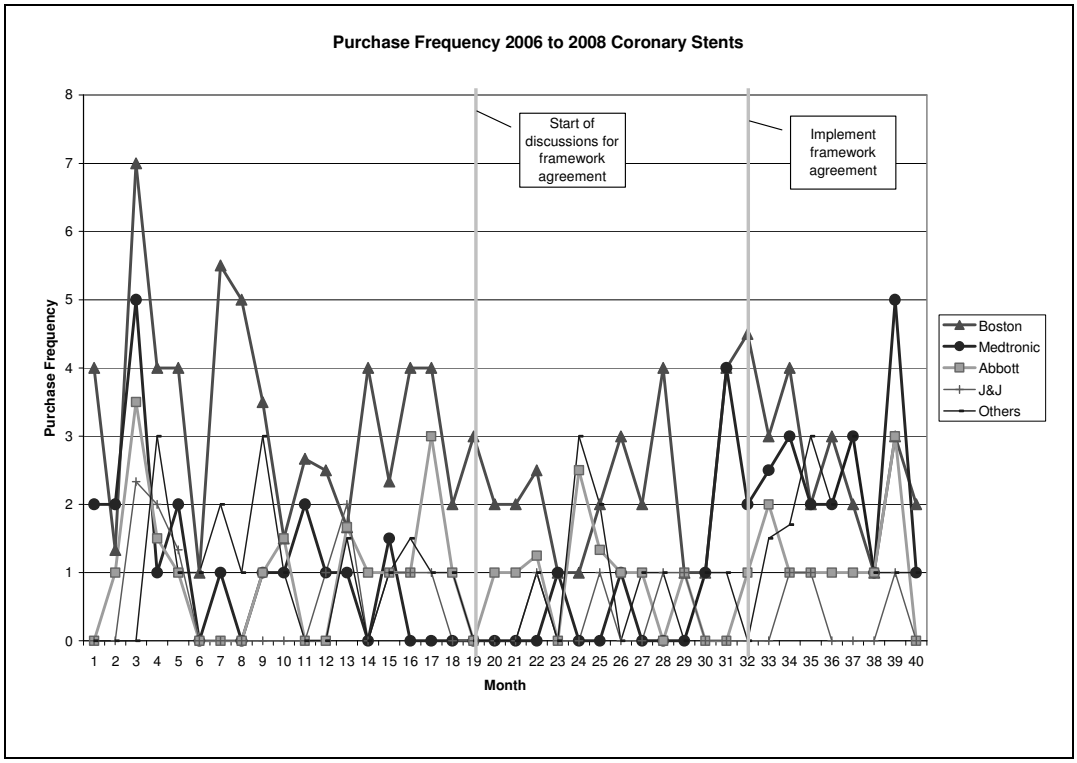

Figure 7.3 Monthly purchase frequency by supplier

Figures 7.2 and 7.3 show that there are few periods where the purchasing behaviour captured in this particular data set can be considered as stationary. Tables 7.4 and 7.5 compare the predicted purchasing behaviour based on the first six months of the data set and on an average six month period (averaged over the first 36 months). Table 7.4 presents the predictions for a six month period and Table 7.5 the predicted behaviours for the 36 month period. It can be seen from the correlations and the Mean Absolute Deviation that there is an approximate fit between the observed data and the predictions for both base periods. In both cases the fit deteriorates when the predictions are extended to 36 months although the average six months does a better job of predicting behaviours over this period. This analysis shows that the long term behavioural patterns are relatively stable and can be accommodated by averaging over the period of analysis. The initial conditions (first six months) provide less good predictions of three year performance than the averaged conditions, demonstrating that there are some changes in behaviour over the three years.

The purchasing intervention is made in the last six months of 2008 and to isolate the effect of this intervention and any other dynamic market developments over the three years, it is necessary to carry out the longitudinal analysis using time periods shorter than the full three years. The charts of market share and purchase frequency show that there is considerable month to month non-stationarity and to average out some of the month to month variations for the NBD analysis, the model will be parameterised and evaluated over a six month time period in each analysis year.

Table 7.4 Dirichlet predictions (average 6 months, first six months)

		Penetration		Purchase Frequency		SCR	
Base Period	Supplier	**O**	T	**O**	T	**O**	T
Average 6 months	Boston	**18.3%**	26.2%	**8.4**	5.9	**75.5%**	56.8%
	Medtronic	**7.5%**	9.8%	**5.2**	4	**35.1%**	31.1%
	Abbott	**15.0%**	11.6%	**3.2**	4.1	**43.9%**	32.8%
	J&J	**8.3%**	6.6%	**3.0**	3.8	**24.6%**	28.5%
	Others	**12.5%**	10.0%	**3.2**	4.0	**32.7%**	31.3%
	Average Supplier	**12.3%**	12.8%	**4.6**	4.3	**42.4%**	36.1%
	Correlation, *r*	0.83		0.92		0.97	
	Mean Absolute Deviation	3.6%		1.2		7.8%	
First 6 months	Boston	**25.0%**	32.0%	**8.0**	6.2	**78.4%**	46.0%
	Medtronic	**15.0%**	21.1%	**5.0**	3.5	**26.3%**	20.3%
	Abbott	**15.0%**	18.7%	**4.0**	3.2	**33.3%**	17.5%
	J&J	**25.0%**	21.1%	**3.0**	3.5	**18.8%**	20.3%
	Others	**10.0%**	14.4%	**4.0**	2.8	**24.2%**	13.9%
	Average Supplier	**18.0%**	21.5%	**4.8**	3.8	**36.2%**	23.6%
	Correlation, *r*	0.79		0.91		0.95	
	Mean Absolute Deviation	5.0%		1.2		13.2%	

Table 7.5 Dirichlet predictions (3 year)

		Penetration		Purchase Frequency		SCR	
Base Period	Supplier	**O**	T	**O**	T	**O**	T
Average 6 months	Boston	**50.0%**	40.8%	**18.5**	22.6	**67.3%**	52.1%
	Medtronic	**20.0%**	18.4%	**11.8**	12.7	**31.1%**	22.8%
	Abbott	**35.0%**	21.4%	**8.3**	13.5	**27.1%**	24.7%
	J&J	**30.0%**	12.8%	**5.0**	11.7	**12.4%**	20.0%
	Others	**30.0%**	18.7%	**8.0**	12.8	**32.9%**	23.0%
	Average Supplier	**33.0%**	22.4%	**10.3**	14.7	**34.2%**	28.5%
	Correlation, *r*	0.86		0.91		0.95	
	Mean Absolute Deviation	10.6%		4.3		8.7%	
First 6 months	Boston	**50.0%**	47.4%	**18.5**	25.3	**67.3%**	44.7%
	Medtronic	**20.0%**	37.2%	**11.8**	12.1	**31.1%**	17.4%
	Abbott	**35.0%**	34.4%	**8.3**	10.5	**27.1%**	14.2%
	J&J	**30.0%**	37.2%	**5.0**	12.1	**12.4%**	17.4%
	Others	**30.0%**	28.9%	**8.0**	8.3	**32.9%**	10.3%
	Average Supplier	**33.0%**	37.0%	**10.3**	13.7	**34.2%**	20.8%
	Correlation, *r*	0.65		0.87		0.85	
	Mean Absolute Deviation	5.7%		3.3		15.4%	

7.2.3 Summary Statistics

Table 7.6 (a) – (c) shows the product category summary statistics for 2006, 2007 and 2008. The total purchases differ slightly from those shown in Table 7.3

because the "year" in Table 7.3 is taken to be 48 weeks (12 equal 4 week periods) rather than calendar months. The tables show the typical Dirichlet patterns of market share and penetration with a wide range between the market leader and the smallest suppliers.

The typical Dirichlet patterns are maintained in the market shares through 2006 to 2008 but become less marked for the penetration measure. In 2008, the combined penetration of the smaller suppliers "Others" (including Biotronik, Atrium, Orbis Neich, B Braun and Terumo) is 20%, compared to the penetration of 15% for Boston. The corresponding market shares are respectively 20.4% and 46.9%. Typically the highest market share supplier will have the largest number of buyers (i.e. the highest penetration). The unusual behaviour in 2008 results from a relatively small population of buyers, a high frequency purchaser who is solely loyal to Boston and the effect of aggregating five separate suppliers into a single combined supplier.

Purchase frequencies are expected to be roughly similar across all suppliers in a typical Dirichlet market, with a tendency for lower share suppliers to have a lower purchase frequency, the Double Jeopardy effect. However Table 7.6 shows that in the case of the coronary stent category there is a wide range of purchase frequencies. In particular Boston has a consistently high purchase frequency, a pattern that becomes more marked through the three years. As will be seen in Section 7.3.3, this is the result of a heavy purchasing segment that favours Boston over the smaller suppliers. The effect is more marked in 2007 and 2008 due to a single high frequency buyer that is solely loyal to Boston and

the dominant effect of a few very frequent purchasers when the overall number of purchasers of the product category declines.

Table 7.6 Summary statistics 2006 - 2008

(a) 48 weeks 2006 Summary Statistics

	Total 12 Months (2006)				
Supplier	Number of Purchases	Number of Buyers	Purchase Frequency	Penetration	Market Share
Boston	84	7	12.0	35.0%	53.5%
Medtronic	22	4	5.5	20.0%	14.0%
Abbott	20	4	5.0	20.0%	12.7%
J&J	16	5	3.2	25.0%	10.2%
Biotronik	12	2	6.0	10.0%	7.6%
Atrium	0	0	0.0	0.0%	0.0%
Orbus Neich	1	1	1.0	5.0%	0.6%
B Braun	2	1	2.0	5.0%	1.3%
Terumol	0	0	0.0	0.0%	0.0%
Total	157	10	15.7	50.0%	

(b) 48 weeks 2007 Summary Statistics

	Total 12 Months (2007)				
Supplier	Number of Purchases	Number of Buyers	Purchase Frequency	Penetration	Market Share
Boston	43	3	14.3	15.0%	48.3%
Medtronic	4	3	1.3	15.0%	4.5%
Abbott	24	6	4.0	30.0%	27.0%
J&J	6	3	2.0	15.0%	6.7%
Biotronik	1	1	1.0	5.0%	1.1%
Atrium	2	1	2.0	5.0%	2.2%
Orbus Neich	7	1	7.0	5.0%	7.9%
B Braun	1	1	1.0	5.0%	1.1%
Terumol	1	1	1.0	5.0%	1.1%
Total	89	7	12.7	35.0%	

(c) 48 weeks 2008 Summary Statistics

	Total 12 Months (2008)				
Supplier	Number of Purchases	Number of Buyers	Purchase Frequency	Penetration	Market Share
Boston	53	3	17.7	15.0%	46.9%
Medtronic	23	2	11.5	10.0%	20.4%
Abbott	10	2	5.0	10.0%	8.8%
J&J	4	1	4.0	5.0%	3.5%
Biotronik	0	0	0.0	0.0%	0.0%
Atrium	7	2	3.5	10.0%	6.2%
Orbus Neich	3	1	3.0	5.0%	2.7%
B Braun	6	2	3.0	10.0%	5.3%
Terumol	7	1	7.0	5.0%	6.2%
Total	113	6	18.8	30.0%	

The changes between 2006 and 2008 can also be observed using the data in Table 7.6. The drop in the number of purchases in 2007 is due to both fewer purchasers and those purchasers purchasing less often. When the number of purchases increases again in 2008, this is due to a recovery in purchasing frequency (the number of purchasers actually falls). Just as the lessons of the Dirichlet teach marketers that the way to sustainable sales volume increases is to

acquire more customers rather than getting existing customers to buy more, so the lesson for purchasing management would appear to be that reductions in purchase frequency may reduce purchased volumes for a short period, but such interventions are unlikely to be sustainable, particularly when demand is derived as in this case where the requirement for stents is governed by the number of cardiac operations carried out.

The observed reduction in the number of purchases is likely to be due to short term inventory reductions, either as a response to increased scrutiny of cardiac stent purchases or in anticipation of cheaper stents after the framework agreements are put in place. The Dirichlet analysis does not consider purchase quantity and it is possible that the buyers are placing fewer, larger orders. However, limited order quantity data is available and analysis of this shows no major changes in order quantity (see Section 7.3.3.1).

There are no dramatic changes in the distribution of purchases between 2006 and 2008. Boston stays at around 50% share, although this is slowly reducing. There is more year to year movement between the other suppliers although the only sustained changes in supplier position appear to be J&J's decline in market share and the increased share taken by the smaller suppliers. The combined share of the five smallest suppliers (Biotronik, Atrium, Orbus, B Braun and Terumo) grows from 9.5% in 2006 to 13.4% in 2007 and 20.4% in 2008.

7.3 Data Analysis and Interpretation

7.3.1 Sample Frame

It has already been seen that the month to month market share and purchase frequency for particular suppliers is highly variable, violating the NBD-Dirichlet assumption of stationarity. To accommodate this variability by averaging over a relatively long time period, the model is parameterised using a 6 month period from each year and tested for goodness of fit against this period and a contiguous, successive 6 month period. The sample and test periods are taken to be the first 6 months and the last 6 months of each year. The sample periods and their corresponding hold-out samples are 2006, weeks 1 to 24 and weeks 25 to 48, 2007, weeks 1 to 24 and weeks 25 to 48 (weeks 53 to 76 and 77 to 100 in the full three year data set) and 2008, weeks 1 to 24 and weeks 25 to 48 (weeks 105 to 128 and 129 to 152 in the three year data set). Loyalty performance measures (proportion of sole buyers and share of category requirements) are also compared across the three year period, including analysis of performance in the last six months of the analysis period following the implementation of the framework agreements.

7.3.2 Purchase Distributions

The purchase distributions (i.e. proportion of purchasers making 0, 1, 2, 3, … purchases in the time period) predicted by the NBD are compared to the observed distributions (Table 7.7). A simple correlation test is used to assess the fit between the predicted and observed distributions for both the base period (i.e. the period used to fit the distribution) and the hold-out period. The Mean Absolute Deviation is also calculated.

Table 7.7 Comparison between observed and predicted distribution of purchases

Year	Supplier	Correlation between observed and theoretical distributions (r)		Mean Absolute Deviation between observed and theoretical distributions		Observed distribution
		Base Period	Hold-out Period	Base Period	Hold-out Period	Standard Deviation
2006	Boston	0.76	0.69	10.7	8.6	20.3
	Medtronic	-0.22	-0.25	19.0	21.6	23.6
	Abbott	-0.02	0.06	15.1	14.1	16.7
	J&J	0.67	0.91	12.2	13.0	22.6
	Others	-0.15	0.57	19.1	10.4	22.1
	Any	0.91	0.91	6.0	4.5	15.9
2007	Boston	0.53	0.38	10.4	14.5	16.7
	Medtronic	-0.04	0.95	20.2	10.2	33.3
	Abbott	0.63	0.31	9.7	13.0	16.7
	J&J	-0.13	0.17	21.0	18.1	33.3
	Others	-0.16	-0.21	19.2	21.6	22.1
	Any	0.55	0.40	9.1	11.2	11.8
2008	Boston	0.12	0.73	16.4	10.8	22.1
	Medtronic	-0.11	-0.12	18.5	20.8	22.1
	Abbott	-0.04	0.00	20.2	17.3	33.3
	J&J	0.15	0.15	18.1	18.1	33.3
	Others	0.62	0.45	10.6	12.4	23.6
	Any	0.51	0.92	9.8	6.1	14.5

The observed and expected distributions are plotted to determine the fit and to identify any systematic biases (Figure 7.4 to Figure 7.9). The small number of purchasers means that the observed distributions are not smooth but have a sawtooth pattern. When the overall number of buyers of a particular supplier is small (for example 2 or 3 buyers) an individual buyer can represent 50% or 33% of the population.

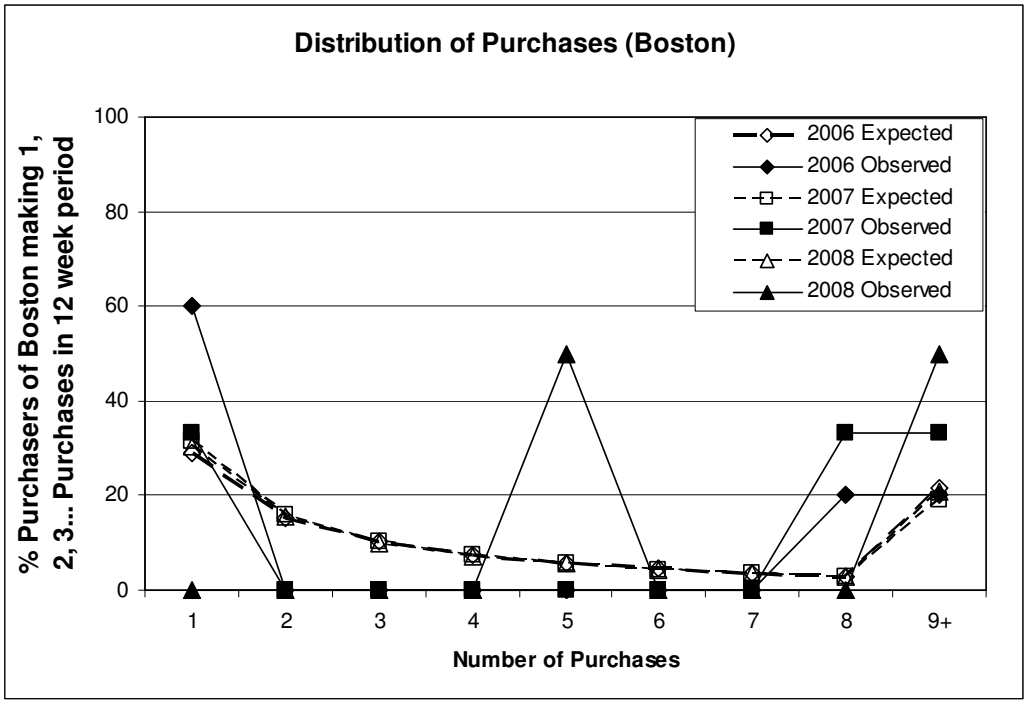

Figure 7.4 **Expected and observed distribution of purchases (Boston) 2006 – 2008**

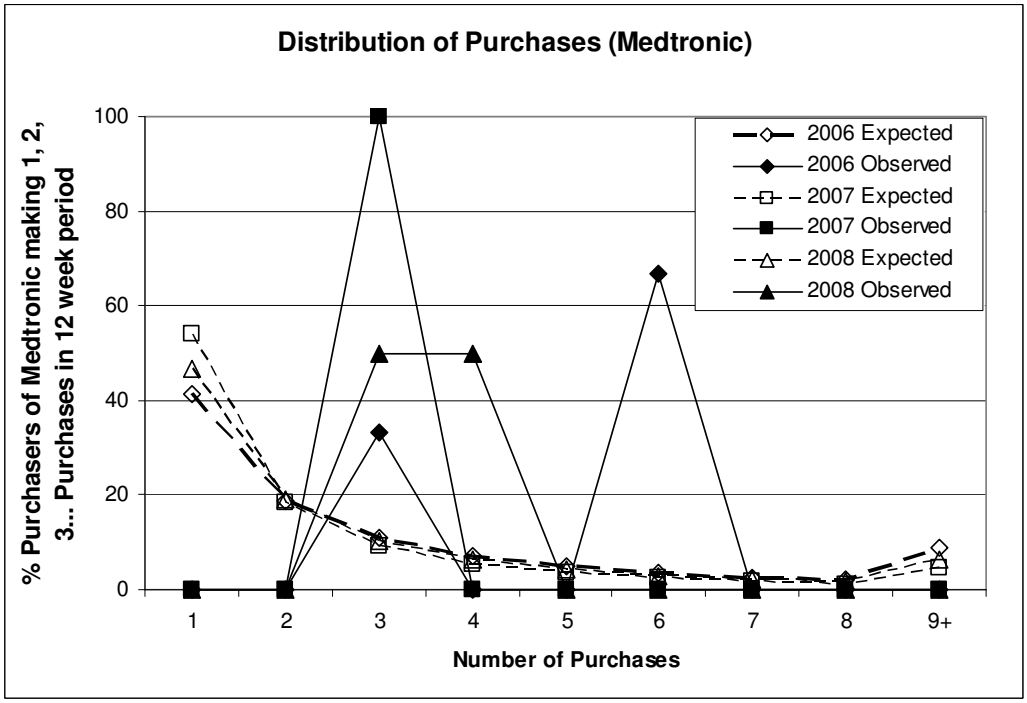

Figure 7.5 **Expected and observed distribution of purchases (Medtronic) 2006 – 2008**

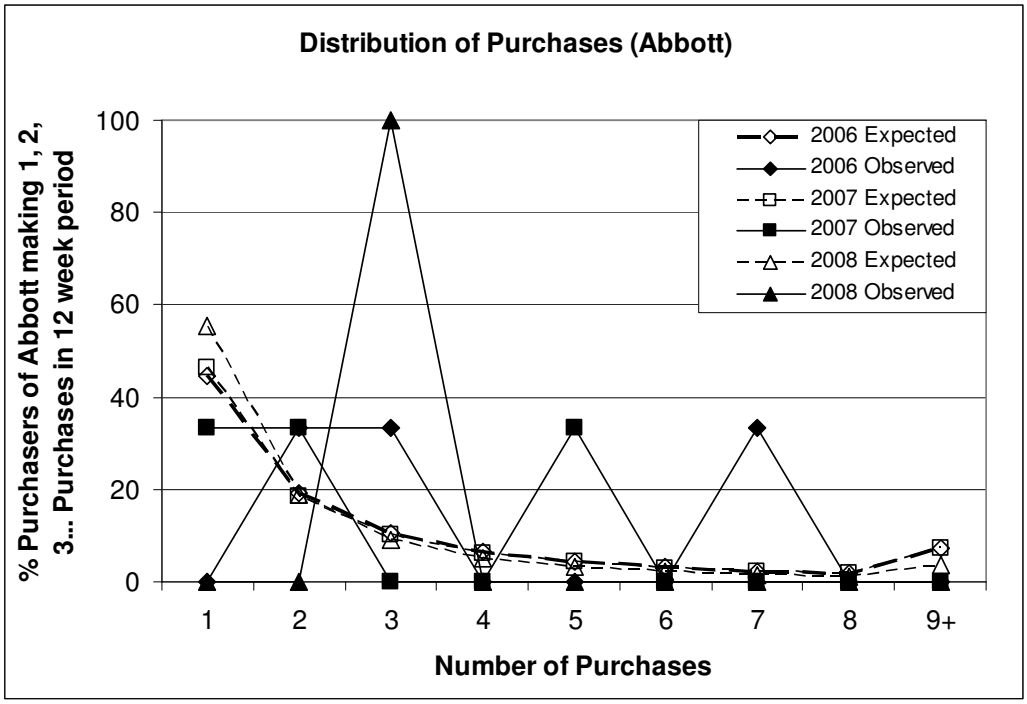

Figure 7.6 **Expected and observed distribution of purchases (Abbott) 2006 – 2008**

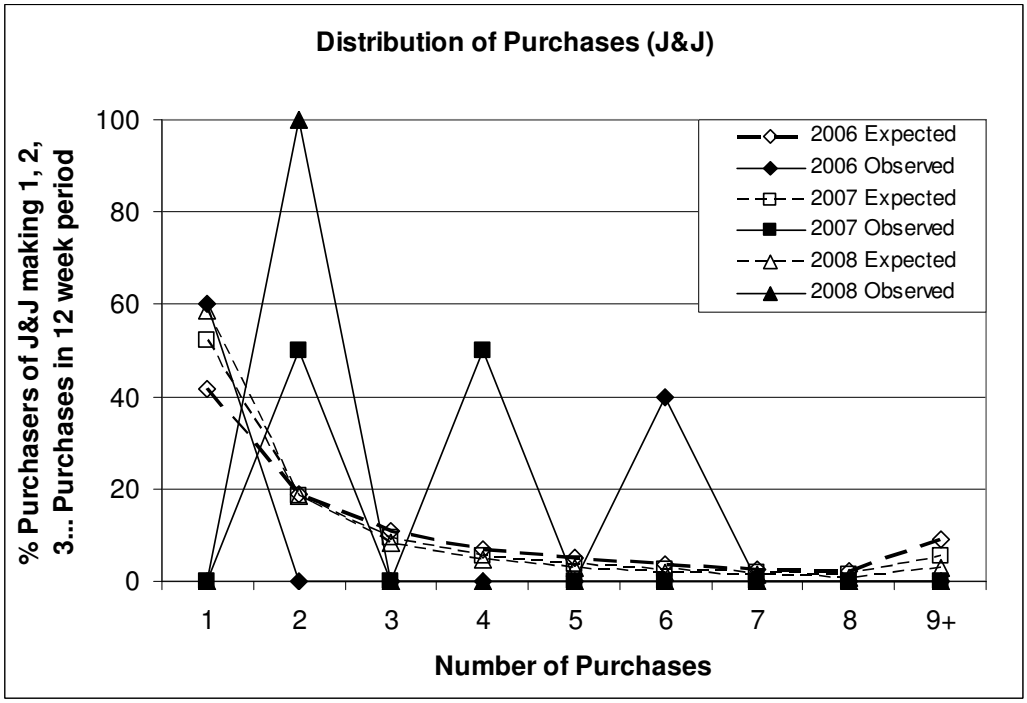

Figure 7.7 **Expected and observed distribution of purchases (J&J) 2006 – 2008**

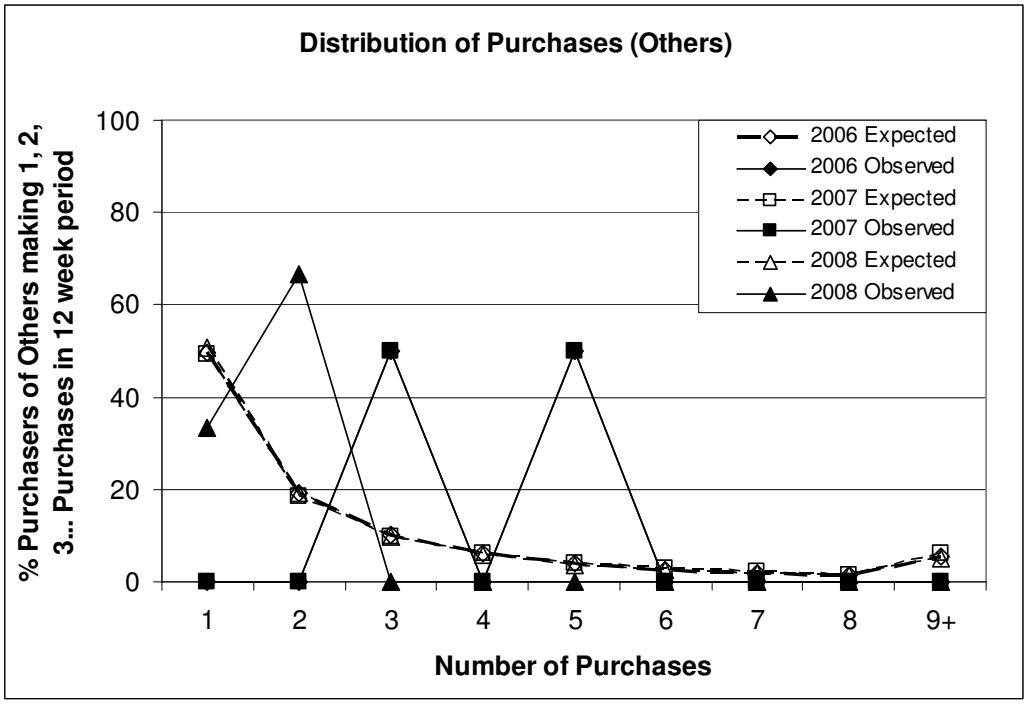

Figure 7.8 **Expected and observed distribution of purchases (Others) 2006 – 2008**

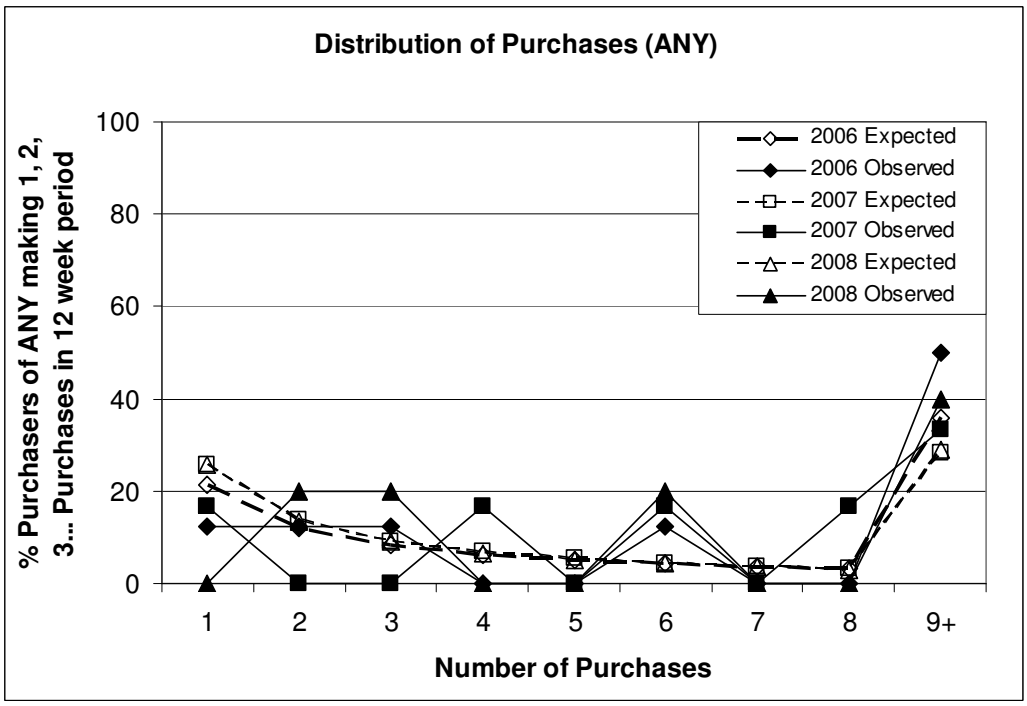

Figure 7.9 **Expected and observed distribution of purchases for product category (ANY) 2006 – 2008**

The fit is not good with only four of the 36 cases having a strong correlation ($r >$ 0.9). The charts, particularly those for Medtronic (Figure 7.5), Abbott (Figure 7.6) and the category (Figure 7.9) show a systematic tendency to overestimate the proportion of light buyers and to underestimate the heavy buyers.

As noted in the ureteral stents case, the tendency to overestimate light buyers is most marked when the purchasing population is dominated by a small number of purchasers who account for a large number of purchases. In a relatively small buying population the distorting effect of this heavy purchasing segment is amplified, resulting in the poor fit for the overall population. For example, Figure 7.6 shows how a single buyer, making three purchases in the 2008 data series, distorts the overall comparison. The consolidation in the buying population can also be seen in the reduction in the proportion of light buyers of Boston and for the category between 2006 and 2008 (Figure 7.4).

7.3.3 Penetration Growth

The observed and expected 6 month penetration rates and purchase frequencies for each supplier are presented in Table 7.8. This shows the performance measures for each year and for the six months immediately after the implementation of the framework agreements (2008, months 7 – 12).

It can be seen from the table that the number of purchasers of each supplier (measured by the penetration) declines sharply across the three years. The category penetration (i.e. the number of buyers who purchase on at least one occasion, from any supplier) decreases from 40% in 2006 to 25% in the first six months of 2008 although it does pick up to 35% in the last six months of 2008, after the agreements are implemented. The average observed purchase

frequency is fairly constant through 2006 to 2008 although it does increase in the last six months. This decline and subsequent rebound has been noted before. The reduction in activity is likely to be due to inventory reduction in anticipation of the negotiation of attractive prices in the framework agreements. Once the agreements are implemented, purchasing activity resumes and inventories start to be rebuilt.

The performance of the individual suppliers can also be tracked to identify shifts in market position over the three years. In most cases, a reduction in market share is the result of a reduction in penetration (i.e. fewer purchasers). This is the case for Medtronic in 2007 and Abbott in 2008 but the most dramatic decline is for J&J, which goes from being purchased by 25% of the buying population in 2006 to a 5% penetration in 2008. J&J's market share reduction over the same period is from 10.2% to 3.5% (see Table 7.6). This decline predates any purchasing interventions and appears to be due to J&J losing buyers through poor service and marketing (see Section 7.4.1).

Boston also loses customers over the three years; its penetration falls from 25% in 2006 to 10% in 2008, although recovers to 15% by the end of 2008. However, over this period Boston maintains a dominant market share with a slight decline from 53.5% to 46.9% and a further decline to 44% in the last six months of 2008. The market position is maintained despite having fewer buyers because those buyers that stay with Boston tend to be heavy purchasers. Thus the purchase frequency of buyers of Boston increases through the analysis period.

Table 7.8 Observed and expected performance measures (6 month)

Year	Supplier	Penetration		Purchase Frequency	
		O	T	**O**	T
2006	Boston	**25.0%**	32.0%	**8.0**	6.2
	Medtronic	**15.0%**	21.1%	**5.0**	3.5
	Abbott	**15.0%**	18.7%	**4.0**	3.2
	J&J	**25.0%**	21.1%	**3.0**	3.5
	Others	**10.0%**	14.4%	**4.0**	2.8
	Average Supplier	**18.0%**	21.5%	**4.8**	3.8
	Correlation, *r*	0.79		0.91	
	Mean Absolute Deviation	5.0%		1.2	
2007	Boston	**15.0%**	24.8%	**9.3**	5.6
	Medtronic	**5.0%**	5.8%	**3.0**	2.6
	Abbott	**15.0%**	12.5%	**2.7**	3.2
	J&J	**5.0%**	7.4%	**4.0**	2.7
	Others	**10.0%**	10.2%	**3.0**	4.5
	Average Supplier	**10.0%**	12.1%	**4.4**	3.4
	Correlation, *r*	0.80		0.76	
	Mean Absolute Deviation	3.1%		1.5	
2008 month 1 - 6	Boston	**10.0%**	21.4%	**13.0**	6.0
	Medtronic	**10.0%**	11.5%	**3.5**	3.0
	Abbott	**5.0%**	6.3%	**3.0**	2.4
	J&J	**5.0%**	4.5%	**2.0**	2.2
	Others	**15.0%**	9.2%	**1.7**	2.7
	Average Supplier	**9.0%**	10.6%	**4.6**	3.3
	Correlation, *r*	0.41		0.98	
	Mean Absolute Deviation	4.1%		1.9	
2008 month 7 - 12	Boston	**15.0%**	23.1%	**11.7**	7.5
	Medtronic	**5.0%**	14.4%	**18.0**	6.2
	Abbott	**10.0%**	6.4%	**3.5**	5.4
	J&J	**5.0%**	2.0%	**2.0**	5.0
	Others	**15.0%**	13.8%	**5.7**	6.1
	Average Supplier	**10.0%**	11.9%	**8.2**	6.1
	Correlation, *r*	0.63		0.63	
	Mean Absolute Deviation	5.1%		4.3	

The fit between the observed (O) and theoretical (T) performance measures presented in Table 7.8 is not good, with the correlation coefficients lower than the 0.9 benchmark and relatively large deviations in most cases. The poor fit between observed and expected performance measures is unsurprising give the poor fit of the underlying NBD distribution as discussed in the previous section.

There appears to be a systematic overestimation of the Boston penetration (the number of buyers) and a corresponding underestimation of the Boston purchase frequency. A similar deviation can be observed for Medtronic in the analysis of the second half of 2008. This deviation is similar to the pattern observed in the ureteral stent case and arises because of the effect of a relatively small number of high frequency purchasers and in the case of Boston, one high frequency purchaser who purchases only from Boston. To accommodate the effect of the heavy purchasers, the purchasing population can be partitioned into two distinct segments – a segment of high frequency purchasers (the top three purchasers by volume in each year) and one of lower frequency purchasers (Table 7.9).

Table 7.9 compares the goodness of fit achieved when the model is used to predict performance measures for the buying population with the predictions for the heavy and light segments. The observed and expected performance measures themselves are presented in Tables 7.10 and 7.11 for the heavy and light segments respectively. It has not been possible to fit the model for heavy purchasers in 2006 or for the last six months of 2008 using a six month base period. These three purchasers average more than one purchase per week and a shorter base period (3 months) is used to converge on a solution for the NBD which is then used to predict the six month performance measures.

Table 7.9 Comparison of goodness of fit between full buying population, heavy segment and light segment

(a) Penetration

Year	Correlation between observed and theoretical distributions (r)			Mean Absolute Deviation between observed and theoretical distributions (%)		
	Unsegmented	Heavy	Light	Unsegmented	Heavy	Light
2006	0.79	-0.61	0.8	5.0%	3.1%	3.0%
2007	0.80	0.94	0.99	3.1%	1.5%	0.9%
2008 months 1 to 6	0.41	0.60	0.97	4.1%	2.3%	0.4%
2008 months 7 to 12	0.63	0.93	0.95	5.1%	2.1%	1.4%

(b) Purchase Frequency

Year	Correlation between observed and theoretical distributions (r)			Mean Absolute Deviation between observed and theoretical distributions (%)		
	Unsegmented	Heavy	Light	Unsegmented	Heavy	Light
2006	0.91	0.94	0.67	1.2	5.0	1.0
2007	0.76	0.94	0.97	1.5	1.5	0.2
2008 months 1 to 6	0.98	0.98	0.98	1.9	1.8	0.2
2008 months 7 to 12	0.63	0.91	0.89	4.3	3.5	0.3

It can be seen that the fit for the heavy and light segments is generally better than that for the full buying population on both measures of correlation coefficient and Mean Absolute Deviation. The NBD-Dirichlet describes penetration rates and purchase frequency with good accuracy although some deviations remain, notably for the heavy segment in 2006 where a single purchaser accounts for all the purchases of Boston in the period. Separating out the light and heavy segments also allows the dynamics of market development in each segment to be analysed. Comparing Tables 7.10 and 7.11, it can be seen that Boston improves its position in the heavy segment, increasing penetration at a time when all other suppliers are experiencing reductions in penetration in this segment. Conversely by 2008, Boston's penetration in the light purchasing segment has fallen to zero.

Table 7.10 Observed and theoretical performance measures, heavy purchasers

Year	Supplier	Penetration		Purchase Frequency	
		O	T	**O**	T
2006*	Boston	**5.0%**	14.2%	**29.0**	10.2
	Medtronic	**10.0%**	9.6%	**4.5**	5.1
	Abbott	**10.0%**	10.5%	**5.0**	5.7
	J&J	**15.0%**	11.2%	**4.3**	6.3
	Others	**10.0%**	11.7%	**4.0**	6.8
	Average Supplier	**10.0%**	11.5%	**9.4**	6.8
	Correlation, *r*	-0.61		0.94	
	Mean Absolute Deviation	3.1%		5.0	
2007	Boston	**10.0%**	13.2%	**13.5**	10.2
	Medtronic	**5.0%**	3.0%	**3.0**	5.0
	Abbott	**0.0%**	0.0%	**0.0**	0.0
	J&J	**5.0%**	3.8%	**4.0**	5.2
	Others	**5.0%**	3.8%	**4.0**	5.2
	Average Supplier	**6.3%**	6.0%	**6.1**	6.4
	Correlation, *r*	0.94		0.94	
	Mean Absolute Deviation	1.5%		1.5	
2008 month 1 - 6	Boston	**10.0%**	13.5%	**13.0**	9.6
	Medtronic	**5.0%**	5.9%	**4.0**	3.4
	Abbott	**5.0%**	4.8%	**3.0**	3.1
	J&J	**5.0%**	3.5%	**2.0**	2.8
	Others	**10.0%**	4.8%	**1.7**	3.1
	Average Supplier	**7.0%**	6.5%	**4.7**	4.4
	Correlation, *r*	0.60		0.99	
	Mean Absolute Deviation	2.3%		1.3	
2008* month 7 - 12	Boston	**10.0%**	13.1%	**17.0**	13.0
	Medtronic	**5.0%**	9.0%	**18.0**	10.0
	Abbott	**5.0%**	3.8%	**6.0**	7.8
	J&J	**0.0%**	0.0%	**0.0**	0.0
	Others	**5.0%**	7.2%	**13.0**	9.1
	Average Supplier	**6.3%**	8.3%	**13.5**	10.0
	Correlation, *r*	0.93		0.91	
	Mean Absolute Deviation	2.1%		3.5	

* Fitted using 3 month base period rather than 6 months

Table 7.11 Observed and theoretical performance measures, light purchasers

Year	Supplier	Penetration		Purchase Frequency	
		O	T	**O**	T
2006	Boston	**20.0%**	19.3%	**2.8**	2.8
	Medtronic	**5.0%**	14.2%	**6.0**	2.1
	Abbott	**5.0%**	6.8%	**2.0**	1.5
	J&J	**10.0%**	6.8%	**1.0**	1.5
	Others	**0.0%**	0.0%	**0.0**	0.0
	Average Supplier	**10.0%**	11.8%	**2.9**	2.0
	Correlation, *r*	0.80		0.67	
	Mean Absolute Deviation	3.0%		1.0	
2007	Boston	**5.0%**	3.6%	**1.0**	1.4
	Medtronic	**0.0%**	0.0%	**0.0**	0
	Abbott	**15.0%**	13.2%	**2.7**	3.0
	J&J	**0.0%**	0.0%	**0.0**	0.0
	Others	**5.0%**	6.1%	**2.0**	1.6
	Average Supplier	**8.3%**	7.6%	**1.9**	2.0
	Correlation, *r*	0.99		0.97	
	Mean Absolute Deviation	0.9%		0.2	
2008 month 1 - 6	Boston	**0.0%**	0.0%	**0.0**	0.0
	Medtronic	**5.0%**	6.6%	**3.0**	2.3
	Abbott	**0.0%**	0.0%	**0.0**	0
	J&J	**0.0%**	0.0%	**0.0**	0
	Others	**5.0%**	4.6%	**2.0**	2.2
	Average Supplier	**5.0%**	5.6%	**2.5**	2.2
	Correlation, *r*	0.97		0.98	
	Mean Absolute Deviation	0.4%		0.2	
2008 month 7 - 12	Boston	**5.0%**	4.2%	**1.0**	1.2
	Medtronic	**0.0%**	0.0%	**0.0**	0.0
	Abbott	**5.0%**	4.2%	**1.0**	1.2
	J&J	**5.0%**	7.6%	**2.0**	1.3
	Others	**10.0%**	12.9%	**2.0**	1.5
	Average Supplier	**6.3%**	7.2%	**1.5**	1.3
	Correlation, *r*	0.95		0.89	
	Mean Absolute Deviation	1.4%		0.3	

Table 7.10 also shows how it is the heavy segment that holds back purchases during 2007 and 2008 and leads the increase in purchase frequency in the last six months of 2008, after the implementation of the framework agreements. As the heaviest purchasers it is these cost centres that stand to gain the most from the lower unit costs that have been negotiated in the agreements.

7.3.3.1 Order Quantity

The reduction in the number of purchases between 2006 and 2008 has been noted previously and attributed to a reduction in inventories in response to increased scrutiny or in anticipation of better prices following the implementation of the negotiated framework agreements. The reduction in the number of purchase occasions had not been observed directly by the hub but the Deputy Director acknowledged that the launch of the negotiation process one year ahead of the implementation of the framework agreements being implemented had resulted in "some movement", particularly around price levels. The Deputy Director in the hub and the trust Procurement Director both proposed an increase in the number of bulk purchases, perhaps prompted by supplier deals as an alternative explanation for the reduction in purchasing activity in 2007.

The reduction in purchases is also accompanied by a reduction in the number of buyers. This may be an attempt by individual trusts to rationalise cost centres in order to consolidate purchases and so reduce transaction costs while gaining better control over purchasing behaviours. As the Deputy Director of Procurement in the hub commented, "*I think when we start to open these sorts of projects and start to analyse the spend and talk to trusts about what they're*

buying, I think it does generate further discussion internally about how can we manage this spend better and more efficiently".

If buyers were consolidating purchases, the purchase order value and the purchase order quantity would be expected to increase as the number of purchasers and purchase occasions reduced. Purchase quantity is not a parameter used in the Dirichlet analysis – the unit of analysis is the purchase occasion – but the data set provided does include some quantity and cost information. Analysis of this data shows that both the quantity and the cost associated with each purchase occasion decrease over the analysis period and there is an increase in the average quantity per purchase occasion in 2007 (Table 7.12). This increase appears to support the premise that the reduction in purchase occasions in 2007 is due to an increase in bulk buying, perhaps as suppliers try to improve their positions ahead of the framework negotiations. The average order quantity in 2006 is almost the same as that in the first half of 2008, even though the number of purchasers and the number of purchase occasions in H1 2008 is approximately half that in the same period in 2006. The costs have been disguised to protect commercially sensitive information.

Table 7.12 Average order quantity per purchase occasion

Year	Average Quantity per purchase occasion	Average cost per purchase occasion (currency units)	Average cost per stent (currency units)
2006	6.1	9216	1521
2007	9.9	10567	1067
2008 month 1 - 6	5.9	5552	941
2008 month 7 - 12	4.3	4188	974

The analysis shows a reduction in average cost per stent which may be a result of the negotiated price reductions or a change in the product mix to include fewer of the expensive drug-eluting stents. The level of detail in the supplied product descriptions is insufficient to analyse this further. However, the overall pattern of reduced pricing confirms the success of a project designed to deliver "cash releasing savings".

7.3.4 Share of Category Requirements

Table 7.13 shows the observed and theoretical SCR for all suppliers for the entire population and for the heavy and light segments as previously defined. The fit between the model predictions and the observed behaviours is not good for the entire population. In only one case does the correlation coefficient exceed 0.9 and the absolute deviations are large for most suppliers. Segmenting the population into the heavy and light segments improves the fit in most cases although some large deviations remain. As before, the small number of buyers and the relatively low purchase frequency distort the analysis because a small number of purchases means that there are few opportunities to purchase from other suppliers. This is particularly true for the light segment in 2008, leading to high observed SCRs, in particular for J&J where one buyer made one purchase, leading to an SCR of 100% and a large deviation from the theoretical predictions.

There is a systematic bias towards underestimating loyalty for all suppliers. The only exceptions are J&J in 2006 and Abbott in 2007 (light segment) and 2008 (light segment). As discussed in Section 6.3.4, the dependency of SCR on the

number of purchases used to operationalise the model will affect the comparison between observed and expected SCR (Stern & Hammond, 2004).

Table 7.13 Share of Category Requirements

Year	Supplier	Entire population		Heavy Segment		Light Segment	
		O	T	**O**	T	O	T
2006	Boston	**78.4%**	46.0%	**80.6%**	42.8%	**73.3%**	56.8%
	Medtronic	**26.3%**	20.3%	**17.6%**	15.8%	**100.0%**	35.7%
	Abbott	**33.3%**	17.5%	**30.3%**	18.8%	**66.7%**	19.6%
	J&J	**18.8%**	20.3%	**18.8%**	21.9%	**18.2%**	19.6%
	Others	**24.2%**	13.9%	**24.2%**	24.4%	**0.0%**	0.0%
	Average Supplier	**36.2%**	23.6%	**34.3%**	24.7%	**64.6%**	32.9%
	Correlation, *r*	0.95		0.95		0.74	
	Mean Absolute Deviation	13.2%		10.9%		25.9%	
2007	Boston	**77.8%**	59.6%	**90.0%**	72.9%	**16.7%**	20.8%
	Medtronic	**27.3%**	18.0%	**27.3%**	23.9%	**0.0%**	0.0%
	Abbott	**72.7%**	24.9%	**0.0%**	0.0%	**72.7%**	75.8%
	J&J	**50.0%**	19.3%	**50.0%**	25.4%	**0.0%**	0.0%
	Others	**50.0%**	22.0%	**50.0%**	25.4%	**50.0%**	28.3%
	Average Supplier	**55.6%**	28.8%	**54.3%**	36.9%	**46.5%**	41.6%
	Correlation, *r*	0.72		0.95		0.94	
	Mean Absolute Deviation	26.8%		13.9%		5.8%	
2008 months 1 - 6	Boston	**81.3%**	62.1%	**81.3%**	69.2%	**0.0%**	0.0%
	Medtronic	**50.0%**	22.0%	**36.4%**	15.0%	**100.0%**	85.2%
	Abbott	**50.0%**	14.8%	**50.0%**	12.9%	**0.0%**	0.0%
	J&J	**33.3%**	13.2%	**33.3%**	11.0%	**0.0%**	0.0%
	Others	**26.3%**	18.3%	**17.6%**	12.9%	**100.0%**	78.5%
	Average Supplier	**48.2%**	26.1%	**43.7%**	24.2%	**100.0%**	81.8%
	Correlation, *r*	0.88		0.88		1.00	
	Mean Absolute Deviation	22.1%		19.5%		7.3%	
2008 months 7 - 12	Boston	**66.0%**	54.6%	**65.4%**	52.1%	**100.0%**	42.2%
	Medtronic	**56.3%**	40.4%	**56.3%**	34.5%	**0.0%**	0.0%
	Abbott	**30.4%**	32.6%	**31.6%**	23.6%	**25.0%**	42.2%
	J&J	**100.0%**	29.4%	**0.0%**	0.0%	**100.0%**	49.7%
	Others	**70.8%**	39.7%	**68.4%**	29.7%	**80.0%**	65.7%
	Average Supplier	**64.7%**	39.3%	**55.4%**	35.0%	**76.3%**	50.0%
	Correlation, *r*	-0.11		0.89		0.74	
	Mean Absolute Deviation	26.2%		16.4%		27.9%	

Deviations from the Dirichlet predictions of SCR have been noted previously, usually as "excess behavioural loyalty" or a "market share premium" for leading brands (Fader & Schmittlein, 1993). Such deviations have been attributed to the existence of market segments, with particular emphasis on availability. An analysis of the UK bottled water market has identified similar patterns of excess observed loyalty (Singh et al, 2009). In the bottled water case the analysis was carried out on sales data from a single supermarket and the excess observed loyalty was for the supermarket's own brand, an effect attributed to the collection of reward points. Constraints that can restrict real or apparent availability in the organisational purchasing context can include policy (negotiated purchasing agreements), habit or distribution. In the current coronary stent case, as for the ureteral stents, segments based on purchase frequency have already been identified and shown to explain some of the deviations from the Dirichlet benchmarks. In the case of Boston in 2008, one buyer accounts for approximately 80% of Boston purchases, fulfilling all their requirements from Boston. The behaviour of this high frequency, solely loyal buyer dominates the loyalty performance measure for Boston.

The market dynamics can also be investigated by examining the development of the observed loyalty levels. Two major transitions can be identified. The first happens between 2006 and 2007 when the number of purchases and the number of buyers reduces. The second occurs after the implementation of the purchasing agreements halfway through 2008. Each transition will be considered in turn.

In 2006 loyalty to Boston is very high compared to the other suppliers in the category. Purchasers satisfy approximately 80% of their category requirements with Boston, whereas the comparable figure for the supplier with the lowest observed loyalty, J&J, is less than 20%. Buyers of J&J choose another supplier about four times more often than they choose J&J. These patterns are broadly predicted by the model with the major deviation being the excess behavioural loyalty to the market leader, Boston.

Through 2007 and early 2008, as the number of purchases falls, Boston maintains loyalty levels close to 80%. This behaviour is driven by high loyalty (SCR in excess of 90%) in the heavy purchasing segment, with a single buyer remaining solely loyal to Boston. It appears that Boston is becoming entrenched as a dominant supplier (high loyalty by a few heavy purchasers) while the other suppliers are bought by a few heavy purchasers who share their purchases between members of a large extended choice set. Abbott also experiences an increase in observed loyalty, much higher than the expected loyalty. As can be seen by the analysis for the light segment, this deviation can be explained by different buying behaviours in the heavy and light purchasing segments.

Purchasing patterns in the second half of 2008 are quite different to those that have gone before. In particular, the reduction in loyalty to Boston, relatively constant at about 80% over the previous 30 months before falling to 66% in the last six months of 2008, is noteworthy. This decrease in loyalty could indicate a longer-term shift in buying behaviour as a result of the implementation of negotiated purchasing agreements. The awareness generated by the implementation and the associated increased transparency of pricing will have

the effect of promoting alternative suppliers. Whether this is a long term shift or a transient will require analysis over a longer period after implementation of the agreements.

7.3.5 Proportion of Sole Buyers

The proportion of buyers of a particular supplier who only buy from that supplier, the so-called sole buyers, is a widely used loyalty measure. It is typically expected in Dirichlet markets that a supplier has relatively few sole buyers and that the sole buyers have a lower purchase frequency than the general population of buyers. The distorting effect of a single high-frequency sole purchaser on the performance measures for Boston (notably penetration, purchase frequency and SCR) has already been noted. It is instructive to review the sole buying patterns to see this effect in more detail (Table 7.14).

The observed behaviours in 2006 follow the expected pattern, with a low proportion of sole buyers although the observed proportions are distorted somewhat by the relatively small number of purchasers. The purchase frequencies are also low with sole buyers averaging 3.5 purchases compared to 4.8 for the whole population in the same period. By 2007 and early 2008, although the proportions of sole buyers appear to be increasing, this is largely a statistical artefact resulting from the reduction in the number of buyers, such that a single sole buyer represents a larger proportion of the buying population. However, the sole buyer purchase frequency is extremely high compared to both the predicted purchase frequency and the observed frequency for the overall population. This is the result of a single high frequency purchaser entering the market in 2007 and only buying from Boston.

Table 7.14 Proportion of sole buyers

Year	Supplier	Sole Buyers		Sole Buyer Purchase Frequency	
		O	T	**O**	T
2006	Boston	**20.0%**	17.7%	**1.0**	1.6
	Medtronic	**33.3%**	8.0%	**6.0**	1.2
	Abbott	**0.0%**	7.1%	**0.0**	1.2
	J&J	**0.0%**	8.0%	**0.0**	1.2
	Others	**0.0%**	5.9%	**0.0**	1.1
	Average Supplier	**10.7%**	9.3%	**1.4**	1.3
	Correlation, *r*	0.42		-0.01	
	Mean Absolute Deviation	9.7%		1.8	
2007	Boston	**33.3%**	32.6%	**19.0**	2.5
	Medtronic	**0.0%**	9.7%	**0.0**	1.3
	Abbott	**33.3%**	12.8%	**1.0**	1.4
	J&J	**0.0%**	10.3%	**0.0**	1.3
	Others	**0.0%**	11.5%	**0.0**	1.3
	Average Supplier	**13.3%**	15.4%	**4.0**	1.5
	Correlation, *r*	0.69		1.00	
	Mean Absolute Deviation	10.5%		4.2	
2008 months 1 - 6	Boston	**50.0%**	31.6%	**21.0**	2.1
	Medtronic	**50.0%**	10.8%	**3.0**	1.2
	Abbott	**0.0%**	8.0%	**0.0**	1.1
	J&J	**0.0%**	7.3%	**0.0**	1.2
	Others	**33.3%**	9.3%	**2.0**	1.2
	Average Supplier	**26.7%**	13.4%	**5.2**	1.4
	Correlation, *r*	0.62		0.99	
	Mean Absolute Deviation	19.4%		4.8	
2008 months 7 - 12	Boston	**66.7%**	36.7%	**10.5**	5.3
	Medtronic	**0.0%**	25.3%	**0.0**	4.0
	Abbott	**0.0%**	19.8%	**0.0**	3.3
	J&J	**100.0%**	17.7%	**2.0**	3.0
	Others	**33.3%**	24.7%	**1.0**	3.9
	Average Supplier	**40.0%**	24.8%	**2.7**	3.9
	Correlation, *r*	0.06		0.82	
	Mean Absolute Deviation	33.2%		3.3	

After the implementation of the framework agreements the proportion of sole buyers increases as a number of lower frequency purchasers re-enters the market, making only single purchases and thus having no opportunity to be anything other than sole buyers. This is the case for J&J, with one buyer making a single purchase. The high frequency sole buyer continues to only buy Boston but the observed sole buyer purchase frequency is reduced because a second (low frequency) buyer makes a purchase from Boston.

7.3.6 Duplication of Purchase

An analysis of the duplication of purchase behaviour (Table 7.15) shows how the patterns of behaviour have changed from 2006 to 2008 although caution should be exercised due to the low numbers of purchasers. In 2006, most buyers had a relatively wide repertoire (choice set), with buyers of almost all suppliers also purchasing from all four other suppliers. The exception is Boston whose buyers only used the three major suppliers. In 2007 these repertoires shrink such that the maximum number of alternative suppliers used is two. This pattern persists into 2008 for most suppliers although Others is present in the repertoires of the buyers of all the suppliers.

This pattern is rather different to that observed for the ureteral stents and the single trust coronary stent case. In these cases the buyers of the dominant suppliers (particularly the heavy buyers) tended to buy mainly from the dominant suppliers. In the collaborative hub coronary stent case the smaller suppliers are used by the buyers of most other suppliers such that the duplication of purchase observed for Others is higher than would be suggested by its penetration and the Duplication of Purchase Law (Ehrenberg et al, 2004). This

level of duplication is reduced after the implementation of the framework agreement, resulting in patterns more similar to those seen in the previous cases.

In 2006 J&J is the most duplicated supplier. It has already been noted that buyers of J&J are likely to choose an alternative supplier four times more often than they choose J&J. Thus they are familiar with the alternative suppliers and their ability to offer credible substitutes. By 2008 J&J has been eliminated from the repertoires of most buyers.

Table 7.15 Observed duplication of purchase (entire buying population)

Year	First Purchase	Who also purchase from:				
		Second Purchase				
	Buyers who purchase from:	Boston	Medtronic	Abbott	J&J	Others
2006	Boston	-	20.0%	20.0%	60.0%	0.0%
	Medtronic	33.3%	-	33.3%	66.7%	33.3%
	Abbott	33.3%	33.3%	-	66.7%	66.7%
	J&J	60.0%	40.0%	40.0%	-	40.0%
	Others	0.0%	50.0%	100.0%	100.0%	-
	Average observed duplication	31.7%	35.8%	48.3%	73.3%	35.0%
2007	Boston	-	33.3%	33.3%	0.0%	0.0%
	Medtronic	100.0%	-	0.0%	0.0%	16.7%
	Abbott	33.3%	0.0%	-	0.0%	33.3%
	J&J	0.0%	0.0%	0.0%	-	100.0%
	Others	0.0%	0.0%	50.0%	50.0%	-
	Average observed duplication	33.3%	8.3%	20.8%	12.5%	33.3%
2008 month 1 - 6	Boston	-	50.0%	0.0%	0.0%	50.0%
	Medtronic	50.0%	-	0.0%	0.0%	50.0%
	Abbott	0.0%	0.0%	-	100.0%	100.0%
	J&J	0.0%	0.0%	100.0%	-	100.0%
	Others	33.3%	33.3%	33.3%	33.3%	-
	Average observed duplication	20.8%	20.8%	33.3%	33.3%	75.0%
2008 month 7 - 12	Boston	-	33.3%	0.0%	0.0%	0.0%
	Medtronic	100.0%	-	0.0%	0.0%	0.0%
	Abbott	0.0%	0.0%	-	0.0%	100.0%
	J&J	0.0%	0.0%	0.0%	-	0.0%
	Others	0.0%	0.0%	66.7%	0.0%	-
	Average observed duplication	25.0%	8.3%	16.7%	0.0%	25.0%

7.4 Qualitative Analysis

Interviews with two procurement executives in the CPH have provided background and context to aid the interpretation of the Dirichlet analysis. The scope of these interviews is discussed in Section 3.5. A number of broad themes emerge from these discussions, concerning the level of buyer experience and openness to use alternative suppliers, the relationship between suppliers and buyers and the nature of the purchasing intervention.

7.4.1 Buyer Experience and Commitment

Three regional clinical networks of cardiac consultants (the cardiac networks) operate within the CPH. The Cardiology Stakeholder Group, comprising decision makers and influencers for cardiac stent purchases and chaired by a recognised cardiac expert, was formed in July 2007 to develop the stent procurement project. Expert buyer engagement is a key element of purchasing interventions in the hub and the procurement executives look to the clinicians and experts to help drive the projects in terms of what the requirements are and also to help manage the market. The importance of the commitment of these experts is highlighted by the Deputy Director of the hub: *"… so if the consultants are telling the suppliers "Don't worry about the hub. You know we'll just pay lip service to it. We're going to carry on doing what we're doing now. You know there's nothing to worry about." Then the suppliers won't submit competitive prices and won't take the process seriously because they won't see that there is an opportunity for them or even a threat of them losing business."*

The cardiac network have always been proactive in looking at new products coming onto the market and are experienced buyers, generally very aware of what is available to them, familiar with the products and not afraid to look at alternatives. They are further ahead of most other purchasing groups in removing "*a lot of the fog around what suppliers provide*". As an example of this, the CPH Deputy Director of Procurement in the hub observed "*J&J are threatening to put the prices up and trusts are immediately trialling alternatives*". The decline in share for J&J between 2006 and 2008 was also attributed to poor service and marketing. The Deputy Director commented that "*J&J haven't spent much time in the trusts and some of the feedback the network gave us was that we hardly ever see them, you know the reps hardly ever come in, we don't know what they're doing and that's reflected in the spend with them*".

The trust Procurement Director commented that the clinicians were concerned that they might lose influence over their spend on cardiac stents. This "*huge sticking point*" was linked to a fear that they would be forced to buy solely on the basis of price. She reported that a common initial reaction to the project was "*I'm not buying the cheapest*". The long engagement period helped to overcome these fears and to establish the requirements for the project such that clinical choice could be maintained while highlighting opportunities to save money. In addition, the aim was to implement the frameworks "*in the most painless way possible*" which in practice meant no significant supplier rationalisation or changes in practice.

The role of the hub procurement specialists is to provide evidence that alternatives are clinically acceptable, usually by showing that products are being used elsewhere. In this respect the framework agreements have opened up options and encouraged clinicians to consider alternatives. This is welcomed by both hub and clinicians because it introduces more competition, allows more control to be exercised over suppliers and allows more choice for individual treatments.

7.4.2 Relationship between Buyers and Suppliers

The suppliers recognise the consultants as their end customers, not the procurement hub. Before the implementation of the framework agreements, the trust Procurement Director noted that individual trusts will have had their own contracts in place with "*a lot of disparity in prices across the trusts*". It is this disparity that the frameworks seek to eliminate. The difference in prices was not always volume related, with the larger centres not always getting the best prices. During the negotiation period the Deputy Director commented on increased supplier activity as "*the suppliers try to get commitment from the trusts and undermine the [procurement] process*".

The Procurement Director recalled that at the time of the project the procurement hub regarded the cardiac stent category as a "*fairly stagnant*" market with comfortable relationships between clinicians and suppliers. The large purchasers tended to be specialist clinical centres without a commercial focus and were "*flooded with supplier reps*". Although there was room to change, in practice this opportunity was rarely taken.

Under the framework agreements, trusts have committed to place a percentage of volume with certain suppliers in order to get better prices. 90% of annual coronary stent volumes are committed with 10% of volume retained for flexibility to trial new products. The committed volumes are based on historical purchase volumes to avoid the tendency of hubs to overestimate their requirements. A process of negotiation between the trusts ensured that the volume requirements across the hub were maximised while meeting the requirements of each trust to exercise choice over their purchases. The commitment to agreed purchase volumes has generally been good but the Deputy Director in the hub is realistic about the depth of this commitment: *"If there is a supplier offering a product at a lesser price their commitment would be irrelevant and they would make that change and then we would have to deal with that."*

7.4.3 Nature of the Purchasing Intervention

The aim of the purchasing intervention is to deliver cash releasing savings. Since the launch of the framework agreements in September 2008, the accumulated cash savings are estimated to be £3 million. This has been achieved by agreeing price reductions with suppliers against firm volume commitments. The early years of the intervention did not involve any supplier rationalisation but more recently there has been some activity towards standardisation and supplier rationalisation with one of the major trusts voluntarily reducing their choice set of drug eluting stents down to two. The data analysed do not include any periods of supplier rationalisation.

The coronary stent category was one of the first projects identified by the hub and was chosen for intervention because it was a significant area of spend, it was a new area for the hub procurement team and the cardiac network were supportive. Regulatory changes concerning the price differential between drug eluting stents and bare metal stents were expected to bring the prices of drug eluting stents down and raise the prices of bare metal stents in order to meet the maximum £300 price difference. Both of these actions would increase hub expenditure on stents: as the more expensive drug eluting stents became more affordable, volume usage was expected to increase while the prices paid for the current purchased stents would increase. The Procurement Director identified these factors as crucial in convincing the hub that the time was right to "*start to influence and talk to suppliers about changing practice and rationalising across the network*". The project started in August 2007 with an extended period of engagement with customers and suppliers before formally going to tender. The negotiated framework agreements were launched in September 2008. The expected price increases in bare metal stents did not occur and while usage of drug eluting stents did rise initially, this soon reduced again.

Increases in activity in both buyers and supplier organisations have been observed during the evaluation and negotiation phase. The activities of suppliers in trying to undermine the process have been discussed above. In the buying organisation, increased scrutiny over spend in the category "*does generate further discussion internally about how we can manage this spend better and more efficiently*" (Deputy Director, Collaborative Procurement Hub). By bringing more spend into the purchase order system, procurement managers gain better visibility and control over the process compared to a situation

described by the trust Procurement Director where "*they probably had really archaic order numbers that departments had been using for years*". These activities may have resulted in some consolidation of buying centres although this was not an objective of the purchasing intervention. The trust Procurement Director also suggested that data collection improved after implementation of the frameworks and may be an explanation for the increased number of purchasers and increased purchase frequency in the second half of 2008.

7.5 Discussion

The analysis of the coronary stent purchasing data demonstrates that the NBD-Dirichlet model satisfactorily describes the observed purchasing behaviour for the coronary stent category in the collaborative purchasing hub over an extended period during which there are major changes to the market structure.

Deviations from the model behaviour are observed. In some cases these are the result of a relatively small purchasing population. Systematic deviations also arise when the assumptions that underpin the Dirichlet model are violated. These are discussed further below.

7.5.1 Dirichlet Assumptions

Over the full analysis period, average purchasing behaviours remain fairly stable until the implementation of the negotiated framework agreements. The fit of the model is good when the base period is an average six months (averaged over the three year data set). Comparison of each of the three annual periods shows little change in any of the performance measures of market share, penetration, purchase frequency or SCR, in particular for the dominant supplier, Boston.

Although the average long term behaviour is stable, there is considerable short and medium term variability that violates the Dirichlet assumption of stationarity. Month to month variations in market share and purchase frequency are marked, particularly for the smaller suppliers; there is considerable change in the buying population with new buyers, lapsed buyers and an overall reduction in the number of buyers and the number of purchase occasions. There is also a noticeable change in behaviour following the introduction of the framework agreement, with the share of category requirements for Boston falling from approximately 80% to 66%. The framework agreements are implemented over the last six months of the three year analysis period. When the average performance over the full three years is considered, the performance during the first 30 months dominates the analysis and the impact of the framework agreements cannot be distinguished.

The second assumption that underpins the Dirichlet analysis is that the market is non-partitioned. The analysis has shown that identifying segments based on purchase frequency (heavy and light purchasers) leads to an improved fit between the model predictions and the observed behaviour. This effect is more marked when the buying population is smaller and the heavy purchasers dominate the overall purchasing patterns, as observed in 2007 and 2008. These findings replicate the observations in the ureteral stent case.

7.5.2 Theoretical Implications

The analysis of the coronary stent case represents a further differentiated replication of the NBD-Dirichlet model into a complex public procurement environment. The case demonstrates how the model describes, predicts and

explains the changes in market structure following a supplier intervention, showing how the understanding of buyer behaviour provided by the model adds to the theory of collaborative purchasing.

7.5.2.1 Extension and Replication of the NBD-Dirichlet Empirical Generalisation

Replication studies set out to judge a theory by how generalisable it is over a wide range of conditions (Lindsay & Ehrenberg, 1993; Ehrenberg & Bound, 1993). The objective is not to achieve the best fit between the observed data and the model predictions for a single instance; rather the aim is to find "significant sameness" (Barwise, 1995) over a range of different circumstances. As in the ureteral stent case, the analysis of coronary stents in the collaborative procurement hub is a highly differentiated replication of the NBD-Dirichlet model. Purchasing decisions are influenced by regulatory decisions affecting the use of drug-eluting stents, by collaborative purchasing decisions made within the purchasing hub, by individual trust procurement departments and by the clinicians themselves. The fit of the expected behaviours predicted by the NBD-Dirichlet model with the observed purchasing behaviour patterns have been shown to satisfy the test of "stochastic sameness" (Ehrenberg & Bound, 1993).

The purchasing behaviours in the coronary stent category generally exhibit the regular patterns of buyer behaviour that have been observed in many different markets (Ehrenberg et al, 2004). These regular patterns include the observation that suppliers in the category typically have very different market shares and penetrations but that the purchase frequency for each supplier is approximately constant. The performance of Boston is somewhat anomalous, with a purchase

frequency of 6.2, almost twice the average of the other suppliers of 3.3. Boston's penetration is also lower than would be suggested by its market share. These deviations are attributed to the impact of a single, solely loyal, high frequency purchaser.

The patterns of observed supplier loyalty in the coronary stent case show the typical patterns of a Dirichlet repertoire market (Sharp et al, 2002) where the buyers of a particular supplier tend to buy from other suppliers quite often. This is typical of competitive markets where buyers are highly experienced and have well established supplier choice propensities such that the Dirichlet's zero-order assumption holds (Ehrenberg et al, 2004). Again the single solely loyal purchaser affects the behaviour of Boston such that observed loyalty towards Boston is much higher than loyalty to the other suppliers and higher than the Dirichlet predicted loyalty.

In addition to the specific case of Boston, there is a systematic tendency to underestimate loyalty for all suppliers. These deviations result in part from a violation of the Dirichlet assumption of lack of partitioning (Sharp & Driesener, 2000) with a segment of high frequency buyers dominating the observed purchase behaviours and in part from the relatively small number of buyers and purchases used to operationalise the model (Stern & Hammond, 2004).

7.5.2.2 Application of the NBD-Dirichlet Model to Collaborative Purchasing

The collaborative purchasing literature focuses on the mechanisms by which purchasing consortia arise, their development and their governance (Schotanus & Telgen, 2007). There has been little research into the actual buying

behaviours of organisations within purchasing consortia. The application of the Dirichlet in a collaborative purchasing context provides a coherent theory of purchasing behaviour to describe, predict and explain buyer behaviour in purchasing consortia.

As in the ureteral stent case, the Dirichlet has been used to establish a base case against which deviations in behaviour can be identified and investigated. The coronary stent data covers a period during which a major purchasing intervention is discussed, negotiated and implemented and the Dirichlet benchmarks provide a valuable theoretical tool to analyse the behaviours in the periods before and after implementation. Deviations from the Dirichlet norms can be used as a point of departure for further investigation such as the impact of the solely loyal high frequency purchaser. The collaborative hub coronary stent case also shows how the NBD-Dirichlet can be applied over a series of time periods to analyse the dynamic response to the implementation of a framework agreement. The implementation of the framework agreements leads to a reduction in share of category requirements for the dominant supplier, Boston, reducing the observed excess loyalty. Excess loyalty is attributed to availability constraints (Fader & Schmittlein, 1993), through distribution, policy, habit or perceived lack of credible alternatives. Implementation of the framework agreements affects loyalty by increasing the awareness of credible alternative suppliers and loosening the organisational constraints that hold back adoption of such alternative suppliers (Jarvis & Wilcox, 1977).

7.5.2.3 Anticipatory Purchasing Behaviours

The analysis of the coronary stent data has shown some preliminary evidence for purchase deceleration in the period before the implementation of the framework agreements as buyers defer purchases in anticipation of better pricing after the negotiations are concluded. The evidence is not conclusive and the effect could be the result of increased order quantity per purchase occasion as suppliers offer bulk purchase deals to improve their market position during the negotiation period.

If deferred purchasing does occur, it is likely to lead to the opposite effect to that intended, as following the implementation of the negotiated contracts, buyers increase purchase rates to rebuild inventories. This could push the measured spend after implementation of a framework agreement above the measured spend before the contracts were in place. This effect has some similarities to the acceleration or deceleration and stockpiling of purchases associated with promotions in consumer markets, in particular the deferment (deceleration) of purchases and the stronger effect observed in the heavy buying segment (Neslin et al, 1985; Mela et al, 1998; Macé & Neslin, 2004). There does not appear to be any literature describing this effect in organisational markets.

7.5.3 Managerial Implications

The theoretical predictions of the NBD-Dirichlet model provide norms and benchmarks against which to assess current behaviours and to monitor the impact of managerial interventions (Ehrenberg & Sharp, 2000). The implications of the model for managers in collaborative procurement organisations are discussed below.

7.5.3.1 Buyer Repertoires

Buyers in competitive Dirichlet type markets will typically purchase from a repertoire of several suppliers with fixed long term purchase frequencies and steady supplier choice probabilities (Goodhardt et al, 1984). Purchasing managers who are planning supplier rationalisation interventions should be aware of the buyer repertoire as supplier rationalisation interventions that do not pay heed to highly dependent relationships typically do not deliver the promised benefits (Cousins, 1999). The intervention in the collaborative hub coronary stent case shows a cautious approach to implementation of framework agreements in such a way that clinician choice is not reduced. The increased awareness of alternative supply options that follows the implementation of the framework agreements increases choice for clinicians and leads to more split loyalty purchasing behaviour.

7.5.3.2 Supplier Loyalty

The assumption of as-if random purchasing behaviours where loyalty is split between suppliers in a purchasing repertoire has implications for purchasing managers seeking to make interventions to change the purchasing behaviours of members of the purchasing group (Goodhardt et al, 1984). Buyers appear to welcome variety and choice (Ehrenberg et al, 2004), an observation noted in the collaborative hub coronary stent case. Cardiac stent purchasing in the collaborative hub shows high observed loyalty behaviour towards a single supplier (Boston) until the implementation of the framework agreements. After the agreements are put in place and credible alternatives are available to be added to the buyers' repertoires, the more typical split loyalty behaviours start to emerge. This development is consistent with the argument put forward by Jarvis

and Wilcox (1977) that most repeat purchase behaviour is determined by organisational constraints. When new vendors are evaluated by a collaborative procurement hub and presented as credible alternatives in an approved purchasing list and prices are negotiated centrally these constraints on repeat purchasing behaviour are loosened and split loyalty behaviour emerges.

7.5.3.3 Implementing and Monitoring Interventions

Using the NBD-Dirichlet as a benchmark for purchasing behaviours allows the procurement manager to track the impact of interventions by assessing behaviours before and after implementation. In the coronary stent case, the comparison between behaviours in 2006 – 2008 and the behaviours in late 2008 (after implementation of the agreements) is striking, particularly when the loyalty measures are considered. Post-implementation, the Dirichlet norms can be used as a baseline to check compliance and monitor unexpected behaviours (Ehrenberg et al, 2004), for example the behaviour of the high frequency sole buyer.

An important feature of the collaborative procurement hub coronary stent case framework agreements is the requirement for member organisations to commit to particular purchase volumes from specific suppliers such that the aggregated volume commitments for the hub are met. Expected purchase volumes for each supplier may not be straightforward historical projections if the purchasing patterns are expected to change after implementation of the framework agreements.

The NBD-Dirichlet can be used to predict purchasing behaviours over time periods of different lengths (Ehrenberg, 1988). This feature of the model can be

used by purchasing managers to make volume predictions under different simulated purchasing patterns. This is discussed further in Section 8.3.3.3 where annual (48 week) predictions for coronary stent purchases in 2006 and the first twelve months of the framework agreement are estimated.

7.6 Summary

This chapter has presented the analysis of coronary stent purchasing data for three full years (April 2006 to March 2009) for reporting trusts in a Collaborative Purchasing Hub in the English NHS. The coronary stent category has been a target for a major purchasing intervention and the 2006 – 2008 data set covers the years immediately preceding the formalisation of these interventions in a negotiated set of framework agreements in September 2008. The background to these interventions has been investigated through an exploratory interview process with representatives of the collaborative procurement hub.

There is considerable month to month variation in coronary stent purchasing behaviours and an observable change in purchasing patterns following the implementation of the supplier framework agreements. The share of category requirements for the dominant supplier, relatively constant at approximately 80% through the previous thirty months, falls to 66% in the six months after the implementation of the frameworks. This may be due to increased awareness of credible alternatives as a result of the framework agreements.

Systematic deviations from the Dirichlet model predictions are observed and analysed. A factor contributing to the observed deviations is a single, solely loyal, high frequency purchaser whose actions dominate the analysis of observed

purchasing behaviours, particularly towards the end of the analysis period when there is a smaller number of buyers.

The analysis of the coronary stent case is a further replication and extension of the NBD-Dirichlet into a collaborative public procurement purchasing environment, adding to the Dirichlet literature and a novel contribution to the collaborative purchasing literature. The case also demonstrates how the NBD Dirichlet can provide benchmarks against which the progress of purchasing interventions can be tracked.

The next chapter summarises the research findings and discusses the theoretical contribution of the research. The implications of the findings for purchasing managers in collaborative procurement organisations are discussed, together with practical applications of the NBD-Dirichlet model.

8 Research Implications and Suggestions for Further Research

8.1 Introduction

The preceding empirical analyses have shown that the purchasing of stents in collaborative purchasing organisations follows regular patterns of buyer behaviour similar to those seen in Dirichlet markets (Ehrenberg et al, 2004). Suppliers of both coronary and ureteral stents typically have very different market shares and penetrations but the purchase frequency for each supplier is approximately constant. In addition, the buyers of a particular supplier tend to buy from other suppliers quite often.

Although such patterns are typical of Dirichlet-type markets, the conditions of stationary and non-partitioned markets necessary for the Dirichlet distributional assumptions to be valid do not hold (Goodhardt et al, 1984). Systematic deviations between the observed patterns and those predicted by the NBD-Dirichlet model (Sharp & Driesener, 2000) are observed, including overestimation of the number of buyers (penetration) and underestimation of the purchase frequency. The observed deviations are attributed to partitioning of the market, in particular the existence of a small number of high frequency purchasers who purchase so frequently that they dominate the observed purchase behaviours. Isolating this heavy purchasing segment improves the fit of the model such that the NBD-Dirichlet describes and predicts the observed purchasing patterns with a level of accuracy similar to that seen in previous Dirichlet studies (Ehrenberg, 1994).

The empirical analysis shows that the theoretical predictions of the NBD-Dirichlet model can provide norms and benchmarks against which to assess current behaviours and to monitor the impact of interventions (Ehrenberg & Sharp, 2000). Systematic deviations from the model benchmarks identify aspects of market structure (for example the high frequency "heavy" purchasing segment) or buyer behaviour that aid understanding of the market and assist the identification of opportunities for intervention.

The contributions of the research are considered in more detail below, together with a discussion of the limitations of the research and suggestions for further research.

8.2 Theoretical Implications

The research represents a substantial extension of the NBD-Dirichlet model into a complex public procurement environment and demonstrates how this model, traditionally associated with business-to-consumer marketing, can be applied in business-to-business purchase and supply chain management. In addition to these contributions to the Dirichlet literature and to the purchasing and supply chain management literature, the review of the extant literature reveals an unexpected complementarity between the stochastic modelling research approach and that of the Industrial Marketing and Purchasing (IMP) group. The research shows how analysis of the observed purchasing behaviours and comparison between these and the benchmark behaviours predicted by the Dirichlet model can guide and inform case study research into the network within which such behaviours are embedded.

8.2.1 Extension of the NBD-Dirichlet Empirical Generalisation

As noted in Section 3.2.1 the essence of replication is to judge a theory by how generalisable it is over a wide range of conditions (Lindsay & Ehrenberg, 1993; Ehrenberg & Bound, 1993). The objective is not to achieve the best fit between the observed data and the model predictions for a single instance; rather the aim is to find "significant sameness" (Barwise, 1995) over a range of different circumstances (Ehrenberg, 1994).

The NBD-Dirichlet empirical generalisation has been applied in over fifty product or service categories (Uncles et al, 1995). However, only three of these studies have addressed organisational purchasing behaviours (Uncles & Ehrenberg, 1990; Bowman & Lele-Pingle, 1997; Pickford & Goodhardt, 2000) and none of the studies has considered buyer behaviour in a collaborative purchasing organisation. A study of physicians' prescribing behaviours (Stern, 1994) has demonstrated that the Dirichlet holds in the situation where the product purchased (prescribed) is not consumed by the specifier. However the physicians were not acting as members of a collaborative purchasing organisation and were not subject to the constraints to product choice imposed by membership of a collaborative procurement programme.

The current research is set in the context of a collaborative public procurement organisation, with complex influences and constraints on supplier choice, including regulatory guidance; purchasing policies at both individual trust level and at the level of the purchasing group; and the choices made by individual clinicians (Cox et al, 2005). These specific conditions represent a highly differentiated replication of the NBD-Dirichlet empirical generalisation.

The collaborative hub purchase data covers a three year period during which supplier intervention in the ureteral stent case and purchasing intervention in the coronary stent case result in major changes to market structure. The purchasing behaviours of individual stent requisitioners in the single trust and of cost centres in the collaborative procurement hub exhibit the regular patterns of buyer behaviour that have been observed in many different markets (Ehrenberg et al, 2004). These regular patterns include the observations that suppliers in the category typically have very different market shares and penetrations but the purchase frequency for each supplier is approximately constant. The Double Jeopardy phenomenon where smaller suppliers tend to be purchased less frequently than the larger suppliers (McPhee, 1963) is also observed.

Linked to Double Jeopardy is the Natural Monopoly Phenomenon (McPhee, 1963) where the smaller suppliers tend to be purchased more frequently by heavier purchasers who have more opportunity to experiment and are typically more experienced purchasers than the lighter buyers. In the single trust coronary stent case and the ureteral stent case the observed behaviours do not follow this pattern and the heavier purchasers buy only rarely from the smaller suppliers. This is an initial deviation from the typical Dirichlet patterns and is attributed to constrained supplier choice and availability (Fader & Schmittlein, 1993). Such constraints can arise from supplier framework agreements that result in restricted repertoires. A similar effect has been observed with own (private) label consumer goods which are only available for purchase in their respective stores. This restricted availability means that own label brands typically have fewer buyers who purchase more frequently than expected (Pare & Dawes, 2008).

Purchasing behaviours in the longitudinal coronary stent case are consistent with the natural monopoly phenomenon because the framework agreements are agreed towards the end of the analysis period and in any case the frameworks are designed to maintain the status quo rather than restrict clinician choice.

The patterns of observed supplier loyalty are quite different between the three cases analysed. The two coronary stent cases show the typical patterns of a Dirichlet repertoire market (Sharp et al, 2002) where the buyers of a particular supplier tend to buy from other suppliers quite often. This is typical of competitive markets where buyers are highly experienced and have well established supplier choice propensities such that the Dirichlet's zero-order assumption holds (Ehrenberg et al, 2004). For the ureteral stents the initial loyalty behaviours are typical of a Dirichlet subscription market (Sharp et al, 2002) where buyers of a particular supplier tend to be solely loyal to that supplier. However by the end of the three year analysis period the patterns are much more like a repertoire market. This is to be expected as buyers become more experienced with the alternative supplier and the supplier becomes established in the buyers' purchase portfolios.

Such patterns are typical of Dirichlet-type markets but the operationalisation of the model in all three cases demonstrates some systematic deviations between the observed performance and theoretical predictions. These deviations include a tendency to overestimate the number of buyers (penetration), to underestimate the purchase frequency and to underestimate supplier loyalty. The dynamic development of both stent categories in the collaborative hub over the three year analysis period means that the conditions of stationary and non-partitioned

markets necessary for the Dirichlet distributional assumptions to be valid do not hold (Goodhardt et al, 1984; Sharp & Driesener, 2000). Selection of a shorter time period during which the purchasing behaviour is approximately stationary improves the fit and allows analysis of the dynamic development of the purchase behaviours in a series of snapshots of behaviour at specific points during the analysis period.

Partitioning of the market with a segment of high frequency buyers dominating the observed purchase behaviours is particularly marked in the single trust coronary stent case and the ureteral stent case where the purchasing repertoire of the heavy purchasers is restricted to the major suppliers. Such segmentation violates the Dirichlet distributional assumptions of lack of partitioning and the independence of supplier choices and purchase frequency (Sharp & Driesener, 2000). Such segmentation by purchase frequency has been observed in earlier B2B applications of the Dirichlet, in particular the analysis of foreign exchange services (Bowman & Lele-Pingle, 1997). This may be a repeatable characteristic of organisational markets.

Purchasing interventions to establish framework agreements and to put in place volume commitments act to restrict the availability of alternative suppliers and lead to these observed deviations from the Dirichlet norms (Fader & Schmittlein, 1993). As has already been noted, the framework agreements implemented in the collaborative hub coronary stent case do not attempt to restrict clinician choice and hence the impact of the heavy purchasing segment is less marked. When the NBD-Dirichlet model is operationalised using the heavy purchasing segment it describes and predicts the observed purchasing patterns

with a level of accuracy similar to that seen in previous Dirichlet studies (Ehrenberg, 1994; Uncles et al, 1995).

8.2.2 Application of the NBD-Dirichlet Model to Collaborative Purchasing

The collaborative purchasing literature is focused on describing, defining and theoretically modelling cooperative purchasing – "to explain, predict and understand behaviour concerning the intent, purpose and actual use of cooperatives in procurement" (McCue & Prier, 2006 p. 46). Most of this literature addresses the motivation for the use of collaborative purchasing arrangements (Tella & Virolainen, 2005), the structure and form of purchasing consortia (Bakker et al, 2006a), the evolution of purchasing consortia (Laing & Cotton, 1997) and the critical success factors that influence the successful implementation of collaborative procurement (Schotanus et al, 2010).

The delivery of long term savings in a purchasing consortium requires product standardisation and vendor rationalisation (Chapman et al, 1998) and hence for purchasers to change their behaviours concerning supplier choice (Cohen, 2002). Commitment and compliance to the purchasing group and acceptance of the constraints that membership of the group places on a buyer's freedom of supplier choice are identified in the collaborative purchasing literature as critical success factors (Doucette, 1997; Harland et al, 2007) along with effective monitoring of local procurement behaviour (Rokkan & Buvik, 2003). However, there has been little research into how the members of purchasing groups actually buy and how their purchasing behaviours change as a result of group membership, particularly with respect to supplier loyalty.

The NBD-Dirichlet model has been used to describe and predict buyer behaviour many different product and service categories (Uncles et al, 1995) but it has been a tool used exclusively by sellers rather than purchasers. The Dirichlet models buyer behaviours for a purchasing population and is likely to be of little practical interest for an individual purchaser or purchasing organisation. However, in a cooperative or collaborative purchasing organisation, there is a heterogeneous population of purchasers, good data availability through the purchase order record, and the desire to understand purchaser behaviour, particularly when favourable contract pricing is contingent on the members of the purchasing group making a minimum number of purchases.

As a coherent theory of purchasing behaviour, the Dirichlet is an important addition to the existing theoretical framework of collaborative purchasing which is based on transaction cost economics, the resource based view of the firm, agency theory, network theory and game theory (Schotanus & Telgen, 2007). The assumptions on which the Dirichlet is based are: (i) each buyer has a steady long term average rate of purchasing the product category and these purchases can be described by a Poisson process; (ii) the distribution of light, medium and heavy buyers is distributed according to a gamma distribution; (iii) each buyer chooses a repertoire of suppliers with fixed propensities to choose any particular supplier represented by a multinomial distribution; (iv) these distributions are distributed across the buying population according to a multivariate Beta distribution; and (v) supplier choice is independent of average purchase frequency (Goodhardt et al, 1984). The current research shows how this

characterisation of buyer behaviour provided by the Dirichlet enables analysis and prediction of purchasing behaviours in collaborative purchasing organisations. In the coronary stent cases in particular, the buyers are highly experienced and exhibit the expected patterns of steady split-loyalty purchase propensities that are unaffected by previous purchases (the "zero-order" assumption) (Ehrenberg & Sharp, 2000).

The concept of the purchasing portfolio or repertoire is an important basis for analysing and understanding purchasing interventions associated with standardisation or rationalisation. Supplier development can be understood as an extension to the buyer's repertoire, as evidenced by the performance of Cook in the ureteral stent case. Supplier rationalisation is conceptualised as a restriction to the buyer's repertoire, as seen in the single trust coronary stent case. Although a stationary model, the NBD-Dirichlet can be applied over a series of time periods to allow analysis of dynamic developments in market structure as a result of such purchasing interventions.

The NBD-Dirichlet model also characterises the loyalty behaviours of buyers in collaborative purchasing organisations. All three cases in the current research demonstrate how the model provides a baseline for interpretation of observed loyalty. Deviations from the Dirichlet norms can be used as a point of departure for further investigation such as the identification of distinct purchasing segments within the buying population as seen in the ureteral stent case and the single trust coronary stent case. The collaborative hub coronary stent case shows how the purchasing intervention affects loyalty by increasing the awareness of credible alternative suppliers.

8.2.3 Stochastic Modelling and Industrial Networks – Complementary Views of Organisational Behaviour

As noted in Chapter 2, stochastic modelling and the "markets as networks" research traditions share an approach to knowledge creation that combines empirical observation and theory development in a generative process (Ehrenberg, 1994; Dubois & Gadde, 2002). Although the theoretical foundations of both traditions are very different, they share assumptions about the nature of buyers and sellers and the constraints which govern their interactions. Stochastic modelling and the IMP or "markets as networks" approach both assume heterogeneity with respect to purchasing behaviours across the population of buyers (Ehrenberg, 1959; Hakansson, 1982).

In addition, both traditions also explicitly recognise that buyers and sellers are interdependent and interact between themselves and with others in the network, often in individually unpredictable ways that constrain both managerial autonomy and the ability to act independently (Ford & Hakansson, 2006). In the interaction approach the constraints imposed on managerial intervention have been described as "the myth of independence" and "the myth of action" (Ford et al, 2003). The concept of "as if random" buying behaviour also constrains managerial ability to influence behaviours in steady markets. Short term interventions, for example promotional activity, can have a temporary effect on behaviours but the observed patterns typically revert back to the long term steady probabilities once the promotion ends (Ehrenberg et al, 1994). Many factors influence an individual purchase decision; certainly too many factors to model rigorously and in most cases, outside the marketing manager's control.

Stochastic theories of behaviour accommodate this uncertainty by modelling purchase behaviour probabilistically (Goodhardt et al, 1984).

The use of stochastic models to analyse and interpret buyer behaviour and market structure can add context to network analysis. Just as deviations from the expected behaviour baseline can prompt econometric analyses of the unexpected behaviours (Morrison & Schmittlein, 1988), they can also be a basis for "purposeful sampling" to identify the rich cases most likely to deliver deep understanding of the observed phenomenon (Dubois & Araujo, 2007). However the combination of stochastic modelling and the "markets as networks" approach is relatively rare, perhaps due to the tendency to identify each as a distinct and separate paradigm. The current research develops a theoretical framework to investigate the common ground between these approaches and demonstrates that the complementary insights derived from them can be exploited to improve the understanding of organisational purchasing behaviour (McCabe & Stern, 2009).

Stochastic modelling and IMP both aim to describe, interpret and explain observed regularities in buyer behaviour. Descriptive and explanatory theory develops from observation in a creative process described as abductive (Dubois & Gadde, 2002) or Empirical then Theoretical (EtT) (Ehrenberg, 1994). The research methodology adopted by both research traditions considers behaviour over an extended series of episodes; interactions in the case of IMP (Ford, 2004), purchase occasions in stochastic modelling (Ehrenberg, 1988). While the predominant mode of analysis in IMP research is interpretive, through the medium of the case study (Easton, 1998), the route to generalisability is

empirical, as in the stochastic modelling approach. Multiple sources of evidence in the case study (Easton, 1995b) are analogous to Multiple Sets of Data (Ehrenberg, 1995).

Although the IMP research is based on the observation of long-lasting inter-firm relationships (Hakansson, 1982) it is recognised that such relationships can change as new suppliers take a greater share of a buyer's purchases (Gadde & Mattsson, 1987; Dubois et al, 2003; Kamp, 2005). The current research demonstrates that, in the case of stent purchases in this particular collaborative purchasing hub, buyers tend to purchase within a repertoire of supplier relationships. Single sourcing or sole loyalty behaviour is unusual and observed behavioural loyalties (measured as Share of Category Requirements) is typically around 50%, similar to loyalty levels seen in many consumer markets.

There have been calls to use stochastic techniques "to study the proportion of newly established, continuing and disrupted relationships" (Gadde & Mattsson, 1987). In his comparison of evolutionary economics with the markets-as-networks tradition, Brennan (2006) suggests the use of dynamic simulation modelling and historical studies to extend the understanding of industrial networks. The current research presents such an example of how stochastic modelling can be used to describe and simulate the changing pattern of relationships and interactions between buyers and suppliers over an extended period.

8.3 Managerial Implications

The NBD-Dirichlet is relatively straightforward to operationalise, robust enough to be used across a range of purchasing situations and requires minimal inputs

(Dacko, 2008), yet it provides a comprehensive characterisation of buying patterns. The theoretical predictions of the NBD-Dirichlet model provide norms and benchmarks against which to assess current behaviours and to monitor the impact of managerial interventions (Ehrenberg & Sharp, 2000). The implications of the model and some practical applications for managers in collaborative procurement organisations are discussed below.

8.3.1 Buyer Repertoires

Buyers in competitive Dirichlet type markets will typically purchase from a repertoire of several suppliers with fixed long term purchase frequencies and steady supplier choice probabilities (Goodhardt et al, 1984). The underlying assumption is that buyers are highly experienced such that the steady supplier choice probabilities are unaffected by additional purchases (the zero-order assumption) and that behaviour is largely routinised within the constraints of the purchasing repertoire (Popkowski Leszczyc & Bass, 1998; Ehrenberg et al, 2004).

Purchasing managers may wish to introduce a new supplier or develop an existing supplier to improve competition and increase leverage over the supply base. Such so-called "reverse marketing" (Biemans & Brand, 1995) requires the new supplier to become established in buyer repertoires so that the supplier attracts more buyers (Ehrenberg, 1988). A sustained effort over an extended period is needed to introduce the alternative supplier to an individual buyer's repertoire and for the buyer to develop enough experience for the choice of the new supplier to become routinised. The experience from consumer markets is that short term promotions can temporarily change purchase behaviours but that

purchasing patterns return to the long term averages once the promotional stimulus is removed (Ehrenberg et al, 1994). The ureteral stent case provides a good illustration of the impact of a sustained supplier development effort, albeit an effort initiated by the supplier itself. Between 2006 and 2008 Cook grows its market share from 24% to 59% by increasing penetration (the number of buyers) from 25% to 37.5%. By 2008 Cook is established in the majority of buyer's repertoires.

Purchasing managers planning supplier rationalisation interventions should also be concerned with the buyer repertoire. Supplier rationalisation interventions that do not pay heed to highly dependent relationships typically do not deliver the promised benefits (Cousins, 1999). Managers should ensure that supplier reduction initiatives recognise that buyers have established purchasing repertoires and try to work within the constraints of those repertoires to restrict the size of the portfolio. The intervention in the collaborative hub coronary stent case shows such a cautious approach to implementation of framework agreements in such a way that clinician choice would not be reduced. In the single trust coronary stent case the supplier rationalisation is more advanced and for the heaviest purchasers the repertoire is restricted to the three major suppliers. Duplication of purchase tables can also be analysed to identify credible alternative suppliers that could be substituted for existing suppliers in the repertoire.

8.3.2 Supplier Loyalty

The loyalty shown to particular suppliers in a competitive Dirichlet market tends to be similar across all suppliers. Buyers appear to welcome variety and choice

(Ehrenberg et al, 2004), an observation noted in the collaborative hub coronary stent case. This persistent split-loyalty behaviour typical of Dirichlet markets is advantageous to purchasing managers seeking to encourage competition and choice in a particular category. The assumption of as-if random purchasing behaviours where loyalty is split between suppliers in a purchasing repertoire has implications for purchasing managers seeking to make interventions to change the purchasing behaviours of members of the purchasing group.

The ureteral stent case demonstrates the development of such split-loyalty behaviours. The initial conditions in the ureteral stent case show high levels of sole loyalty such that buyers satisfy most of their requirements from a single supplier. By the end of the analysis period the ureteral stent buyers have gained experience of an alternative supplier and exhibit the split loyalty behaviours typical of a Dirichlet market. Experienced buyers, such as those in the cardiac stent cases already exhibit split loyalty behaviour as is seen in the single trust case. Cardiac stent purchasing in the collaborative hub shows high observed loyalty behaviour towards a single supplier (Boston) until the implementation of the framework agreements. After the agreements are put in place and credible alternatives are available to be added to the buyers' repertoires, the more typical split loyalty behaviours start to emerge.

8.3.3 Practical Applications of the NBD-Dirichlet Model in Purchasing and Supply Management

The NBD-Dirichlet provides theoretical benchmarks that can be used to audit supply categories in order to assess the opportunity for intervention or to monitor the progress of an intervention. It can also be used for scenario

planning, for example to model the introduction of a new supplier, the development of an existing supplier or the removal of an existing supplier. As seen in the current research the Dirichlet can also be used to analyse dynamic market development over an extended period (Ehrenberg et al, 2004).

8.3.3.1 Category Audits

Brand Performance Measures such as market share, penetration, purchase frequency, percentage of heavy buyers, share of category requirements and percentage of solely loyal buyers are commonly benchmarked against Dirichlet norms (Ehrenberg et al, 2004) to assess whether the observed performance matches the performance that would be expected given the brand's market share. The same techniques can be applied to purchase categories in a collaborative hub, to assess whether the observed behaviours are in line with those that would be expected in a competitive Dirichlet market. Deviations from the norms can indicate opportunities for intervention and the magnitude and direction of deviations can be monitored to assess the progress of purchasing management interventions. By way of example, deviations from the Dirichlet norms identified in the current research are discussed below.

In the ureteral stent case the observed penetrations are generally lower than the Dirichlet norms and the observed purchase frequencies generally higher than the benchmarks. These deviations from the Dirichlet predictions are explained by a partitioned market with distinct heavy and light purchasing segments. There are also deviations from the Dirichlet norms in the share of category requirements for the ureteral stents. The observed loyalties are generally higher than the predicted loyalties, a deviation that is also attributed to the existence of the

heavy purchasing segment. In addition, in 2006, buyers of Boston and Cook satisfy approximately 90% of their category requirements from a single supplier, a purchasing pattern that is more like a subscription market than a competitive split loyalty repertoire market (Sharp et al, 2002). These high observed loyalties suggest an opportunity for intervention to expand the buyers' repertoires beyond their single preferred supplier perhaps by building increased awareness of credible alternatives or increased transparency in pricing. By 2008, after a sustained promotional intervention by Cook, the share of category requirements was less than 60% for each supplier.

Similar deviations from the Dirichlet norms are observed in the collaborative hub coronary stent case. In this case the impact of a heavy purchasing segment can also be observed in the number of buyers (penetration) and their purchase frequency. When the share of category requirements for the coronary stents is considered, it can be seen that Boston has a particularly high observed SCR compared to the Dirichlet prediction. This excess loyalty persists until the introduction of the framework agreements in the second half of 2008. Excess loyalty for a market leading supplier has been observed previously (Fader & Schmittlein, 1993). This market share premium is attributed to distributional effects which in the coronary stent case can be interpreted as a perceived lack of credible alternatives. The framework agreements raise awareness of possible alternatives and the market share premium falls.

Deviations from the Dirichlet norms can also be used to track the progress of purchasing interventions and to monitor compliance with framework agreements. The single trust coronary stent case shows that purchasing patterns

can be analysed at the level of the individual requisitioner, rather than the cost centre. Observed excess loyalty for one or more suppliers or higher than expected purchase frequency or penetration for off-framework suppliers would indicate non-compliant or maverick purchasing behaviours. For example, the heaviest purchaser in the collaborative hub coronary stent case buys only from the dominant supplier, even after implementation of the framework agreements. Although the buyer is using a framework supplier, the apparent lack of competition at the particular cost centre could be investigated further by the purchasing group.

8.3.3.2 Identification of Credible Alternative Suppliers

An underlying assumption of the Dirichlet is that markets are non-partitioned, that is, the suppliers within a category supply directly substitutable products. A purchasing intervention to develop a supplier or to introduce a new supplier to a particular group of buyers may require that credible alternative suppliers can be identified. The purchase duplications between suppliers can be used to identify potential alternative suppliers with directly substitutable product. For example, in the collaborative hub coronary stent case J&J is the most duplicated supplier in 2006, with buyers of J&J four times more likely to use an alternative supplier. Buyers may have been seeking alternatives because of the reported poor service from J&J and by 2008 J&J had been eliminated from the repertoires of most buyers.

8.3.3.3 Supply Base Changes

The Dirichlet can also be used to simulate the market response to introduction of a new supplier or a change in market share of a supplier (Ehrenberg, 1991;

Ehrenberg et al, 2004). For example, Table 8.1 shows the predicted purchasing behaviours for the ureteral stent category using the 2006 conditions as the base period and simulating the effect of an increase in Cook's market share to 59% (the level in 2008).

Table 8.1 Simulated 12 week performance measures (ureteral stents) with 2008 market shares

		Penetration		Purchase Frequency		SCR	
Simulation	Supplier	O	T	O	T	O	T
Base period 2006 (12 week) Simulate 2008 (12 week) market shares	Boston	**7.5%**	17.1%	**4.0**	1.6	**60.0%**	57.7%
	Cook	**20.0%**	23.8%	**2.4**	1.9	**63.3%**	71.6%
	Others	**2.5%**	1.8%	**1.0**	1.3	**100.0%**	38.6%
	Average Supplier	**10.0%**	14.2%	**2.5**	1.6	**74.4%**	55.9%
	Correlation, *r*	0.89		0.47		-0.87	
	Mean Absolute Deviation	4.7%		1.1		24.0%	

The accuracy of these predictions is as good as the performance measures predicted using the 2008 base period itself (Tables 6.7 and 6.10).

In a similar way, the effect of a new supplier can be simulated as shown in Table 8.2. Using 2006 as the base period, the new supplier (NewCo) is assumed to secure a 10% market share with Boston on 60%, Cook on 25% and Others on 5%. In this case there is no observed data against which to test the predictions.

Table 8.2 Simulated 12 week performance measures (ureteral stents) with new supplier

Simulation	Supplier	Penetration	Purchase Frequency	SCR
Base period 2006 (12 week) Simulate new market entrant with 10% share of market	Boston	23.9%	1.9	72.0%
	Cook	12.4%	1.5	50.0%
	NewCo	5.5%	1.3	42.1%
	Others	2.9%	1.3	39.5%
	Average Supplier	11.2%	1.5	61.2%

Simulations like those presented in Tables 8.1 and 8.2 can be used by purchasing managers to plan supplier development interventions.

An important feature of the collaborative procurement hub coronary stent case was the implementation of a set of framework agreements to establish consistent, target volume based pricing across the hub. Member organisations

must commit to particular purchase volumes from specific suppliers such that the aggregated volume commitments for the hub are met. Agreeing volume targets requires that the expected purchased volumes for each supplier can be predicted. These predictions may not be straightforward historical projections if the purchasing patterns are expected to change after implementation of the framework agreements.

Table 8.3 Predicted annual performance measures (coronary stents)

		Penetration		Purchase Frequency		SCR	
Simulation	Supplier	O	T	O	T	O	T
Base period 2006 (6 month) Predict 2006 (12 month)	Boston	**35.0%**	33.6%	**12.0**	11.9	**63.2%**	44.9%
	Medtronic	**20.0%**	24.4%	**5.5**	6.2	**22.8%**	18.2%
	Abbott	**20.0%**	22.1%	**5.0**	5.4	**38.5%**	15.2%
	J&J	**25.0%**	24.4%	**3.2**	6.2	**11.5%**	18.2%
	Others	**10.0%**	17.9%	**7.5**	4.5	**34.1%**	11.3%
	Average Supplier	**22.0%**	24.4%	**6.6**	6.8	**34.0%**	21.5%
	Correlation, *r*	0.97		0.78		0.74	
	Mean Absolute Deviation	3.3%		1.4		15.1%	
Base period 2008 (month 7 - 12) Predict 2008/9 (First 12 months of agreement)	Boston		28.0%		12.5		51.9%
	Medtronic		18.0%		10.0		36.9%
	Abbott		8.2%		8.5		28.7%
	J&J		2.5%		7.9		25.4%
	Others		17.3%		9.9		36.2%
	Average Supplier		14.8%		9.8		35.8%

The NBD-Dirichlet can be used to predict purchasing behaviours over time periods of different lengths (Ehrenberg, 1988). This feature of the model can be used by purchasing managers to make volume predictions under different simulated purchasing patterns. Table 8.3 shows annual (48 week) predictions and actual performance for coronary stent purchases in 2006 and predictions for the first twelve months of the framework agreement. In this latter case there is no observed data against which to test the predictions. While these predictions refer to purchase occasions rather than actual purchase quantities, the analysis presented in Chapter 7 suggests that average purchase quantity is relatively constant. Knowing the average purchase quantity and the purchase frequency

per buyer of a particular supplier, the expected volume requirements for that supplier can be predicted.

8.3.3.4 Dynamic Market Development

As has been seen in the current research, the steady state Dirichlet norms can be used to analyse market dynamics through a series of snapshots. In both the ureteral stent and the collaborative purchasing hub coronary stent cases, the Dirichlet model is shown to hold at the beginning and the end of the three year analysis period despite major changes to the market structure in both cases. By comparing the changes in performance measures over the period of analysis the nature of the intervention can be identified (Ehrenberg et al, 2004). For example, in the ureteral stent case, the accumulation of high frequency buyers by Cook is identified as the source of Cook's improving market share.

In the case of coronary stent purchasing in the collaborative hub there is a reduction in purchasing volume from 2006 to 2007. This reduction in purchasing activity may be due to buyers deferring purchases in anticipation of better prices after negotiation of the framework agreements. After implementation of the agreements in the second half of 2008 most, but not all of these buyers return to the market and there is a substantial increase in purchase frequency.

8.4 Limitations and Suggestions for Further Research

The analysis has been constrained by a rather limited data set. Although the dataset covered an extended period, allowing a longitudinal analysis to be carried out, the population of buyers is relatively small, compared to typical consumer panel analyses. The small population leads to increased predictive

uncertainty, particularly over longer time scales. The cost centre data set drawn from the collaborative purchasing hub does not provide the same detail as the individual requisitioner purchasing data from the single trust. Purchasing information is not collected at requisitioner level in the hub. While the data set did cover a period of intervention in both the ureteral and coronary stent cases, it included only a six month period immediately after the implementation of the coronary stent framework agreements. These framework agreements were explicitly intended to maintain the status quo and therefore it was not possible to observe the impact of a purchasing intervention designed to restrict supplier choice or indeed the longer term impact of the implemented agreements.

By using secondary data that records observable occurrences (raising a purchase order), the information gathered for the research is not affected by respondent attitudes or expectations. The aggregation of data from many separate purchasing organisations reduces some of the issues related to non-response, common method variance and bias in survey research (Autry & Golicic, 2010). However, these records are not always complete, particularly for product descriptions. In these cases, errors may be introduced by inaccurate categorisation of the products, either by misallocating products to categories or by excluding products where the description is unclear. In addition there may be systematic under-reporting when purchases are made outside the purchase order system or through incompatible computer systems.

While the research has addressed the “what”, demonstrating that the observed purchasing behaviours exhibit typical patterns that can be described by the NBD-Dirichlet; and the “how”, that buyers buy with a steady long term purchase

frequency and have a stable probability of choosing a particular supplier from a repertoire of suppliers; the "why" is not fully answered. In the ureteral stent case, why does Cook successfully displace Boston as the dominant incumbent supplier? What actions do the purchasing team take to cause such a dramatic change in purchasing patterns following introduction of the framework agreement? The components of these interventions can be elucidated by a deep qualitative case study methodology to "look for the roots of things, to disentangle complexities and to conceptualise and reconceptualise, test and retest, to be both rigorous and creative and above all to seek for the underlying reality through the thick veil which hides it" (Easton, 1998 p.81).

The qualitative element of this research has been limited by access to decision makers in the organisations under study. Organisational change, both imposed by government and internally driven change, means that the individuals involved in the original interventions in 2006 – 2008 are either no longer in post or not available for interview. Two interviews were conducted to develop an understanding of the nature and context of the cardiac stent intervention and to aid the interpretation of the observed purchasing patterns.

With these principal limitations in mind, it is suggested that further research may focus on extending the range of the sample and on more extensive analysis using quantitative and qualitative methods.

8.4.1 Differentiated Replication

This research has been an exploratory study using three distinct data sets in order to apply the Dirichlet model to a collaborative purchasing and supply context. The initial results have been encouraging but further replication studies

will be required to validate the generalisability of the model into the collaborative purchasing environment and the impact of demand side interventions under different market conditions. The observed phenomena of market partitioning (heavy and light buyers), restricted repertoires due to negotiated framework agreements and the associated deviations from the Dirichlet norms such as low penetration, high purchase frequency and excess observed loyalty should be tested to see if they generalise to other collaborative purchasing situations.

Such a replication study should aim to work with a larger buying population, perhaps by extending the overall scope of the analysis. Considering stent purchases, a differentiated replication could encompass the entire NHS rather than just a single collaborative purchasing hub or consider purchase behaviours in other healthcare systems where collaborative purchasing is used. The consolidation of much public procurement under the OGC (Office of Government Commerce) and the intention to make much public sector procurement activity publicly available could improve availability of information for such analysis. The growth of e-procurement provides a means of controlling purchasing behaviours and monitoring those behaviours (Croom & Brandon-Jones, 2007) as well as being a source of good quality purchasing data. Future research should address the impact of e-procurement on purchase behaviours in collaborative purchasing organisations.

An alternative to extending the scope of the sample would be to deepen it. The East of England CPH cases were analysed at the level of the cost centre. Compare this to the pilot data analysis carried out on data from a single trust

where the level of resolution of the data was to the individual requisitioner. Working at this resolution increases the effective buying population under analysis and would also allow purchasing managers to identify individual cases of so-called “maverick” purchasing in a way that is not possible with data consolidated to a departmental level.

A further extension to the current research would be to distinguish between the two coronary stent variants, the drug eluting stents and bare metal stents, in order to investigate the effect of the regulatory price controls on purchasing patterns. The lack of detail in the purchase order product descriptions and the aggregation of both stent types into a single purchase order mean that it has not been possible to differentiate between the variants in the current research.

In addition the observed phenomenon of deferred purchasing in anticipation of better pricing and the subsequent rebound of purchase levels should be investigated further. Additional research is required to establish whether the observations can be replicated in other organisational purchasing situations where an extended evaluation and negotiation period is expected to lead to lower prices.

8.4.2 Extended Case Research

The analysis has shown how the organisational purchasing patterns develop following interventions by suppliers (ureteral stents) and supply managers (coronary stents). These developments have included increases in the number of buyers for particular suppliers, increased duplication of purchases where buyers purchase from an enlarged repertoire of suppliers and changes in the observed loyalty measures. However, the nature of the interventions has not been fully

investigated and further research is required to identify the actions taken and the relative effectiveness of particular actions.

The evolving nature of the network of relationships between the collaborative purchasing hub and its member trusts, suppliers and government would make an interesting and informative case study. Established relationships between trusts and suppliers will have been disrupted by the emergence of the collaborative hub and by the subsequent interventions in the purchasing process.

Such an in-depth longitudinal case study could examine the contingent factors affecting the network and the behaviours of the actors within it to understand the changing behaviours and to develop theoretical explanations of the observed behaviours. The extent to which purchasing behaviour is constrained by supply agreements, by habitual purchasing or by distribution could be investigated, as could the roles and relationships of the various actors in the purchasing process and how these change during the evaluation, negotiation and implementation of the framework agreements.

These case studies would be enhanced and informed by the quantitative analysis presented in this research. Stochastic modelling describes the changing pattern of relationships and interactions between buyers and their repertoire of suppliers and provides context for the selection and interpretation of in-depth case studies (Gadde & Mattsson, 1987). Deviations from the Dirichlet norms can be a basis for "purposeful sampling" (Dubois & Araujo, 2007) to identify the cases most likely to deliver deep understanding of observed phenomena including the impact and sustainability of purchasing and supply management interventions.

8.5 Summary

The research is a highly differentiated replication of the NBD-Dirichlet model in a collaborative public procurement situation. This is a substantial addition to the NBD-Dirichlet literature, extending the generalisability of the NBD-Dirichlet model to new conditions and establishing boundary conditions where the model does not accurately describe or predict the observed behaviours. The observed deviations result from violations of the Dirichlet assumptions, in particular the assumptions of stationary behaviour and non-partitioning. The behaviour of buyers through the analysis period is dynamic with observed changes in supplier choice. In addition a small number of high frequency purchasers purchase so frequently that they dominate the observed purchase behaviours. Isolating relatively short time periods and the heavy purchasing segment improves the fit of the model such that the NBD-Dirichlet describes and predicts the observed purchasing patterns with an acceptable level of accuracy.

Extending the application of the NBD-Dirichlet model into a purchasing and supply context also contributes to the collaborative purchasing literature. By addressing the actual purchase behaviours of member organisations in a purchasing consortium the research adds a new dimension to a literature that has mainly dealt with the establishment, development and operation of the collaborative organisation.

The analysis also shows how the Dirichlet can inform purchasing managers as they analyse purchasing patterns in order to design and implement interventions to change purchasing behaviours. Although a steady state model, the theoretical norms provided by the Dirichlet can be used as benchmarks to assess current

behaviours and to monitor the progress of purchasing management interventions, for example the implementation of purchasing framework agreements.

9 Conclusions

9.1 Introduction

Effective collaborative purchasing arrangements are an important element of purchasing efficiency programmes, particularly in the public sector (Essig, 2000). While transaction costs can be reduced by pooling resources and lower prices achieved through aggregating volumes to increase leverage with suppliers, the long term effectiveness of these arrangements requires product standardisation and vendor rationalisation (Chapman et al, 1998). Standardising on a smaller set of suppliers inevitably requires member organisations to change their supplier choice behaviours such that new suppliers may be introduced or existing suppliers dropped (Cohen, 2002). Despite the importance of purchasing behaviours in determining the success of collaborative procurement arrangements, there has been little research into how the members of purchasing groups actually buy and how their purchasing behaviours change as a result of group membership, particularly with respect to supplier loyalty.

9.2 Research Objectives

Taking this lack of research into actual purchasing behaviour as its point of departure, this study investigates the behaviour of purchasers in a collaborative procurement environment. The specific objectives of the research were (i) to determine if organisational buyers in a collaborative purchasing organisation exhibit regular patterns of purchase behaviour in terms of purchase incidence and supplier choice; (ii) to model the observed behaviours using an established

model of buyer behaviour, the NBD-Dirichlet; and (iii) to provide purchasing managers with metrics and benchmarks to assess and monitor buyer behaviour.

9.3 Research Findings

Using stent purchase data provided by a collaborative procurement hub in the English NHS, the research meets the first research objective by showing that members of this purchasing consortium do exhibit the same regular patterns of buyer behaviour that have been observed in many different markets (Ehrenberg et al, 2004). These regular patterns include the observations that suppliers in the category typically have very different market shares and penetrations but the purchase frequency for each supplier is approximately constant. In addition, the buyers of a particular supplier tend to buy from other suppliers quite often.

Such patterns are typical of Dirichlet-type markets. However, when the second research objective is considered, namely the extent to which the observed behaviours can be modelled using the NBD-Dirichlet model, the fit of the model is not good. The collaborative hub purchase data covers a three year period during which supplier intervention in the ureteral stent case and purchasing intervention in the coronary stent case result in major changes to market structure. The resulting dynamic development of both stent categories over the three year analysis period means that the conditions of stationary and non-partitioned markets necessary for the Dirichlet distributional assumptions to be valid do not hold (Goodhardt et al, 1984). This violation of the Dirichlet assumptions results in systematic deviations between the observed patterns and those predicted by the NBD-Dirichlet model (Sharp & Driesener, 2000).

Selection of a shorter time period during which the purchasing behaviour is approximately stationary allows analysis of the dynamic development of the purchase behaviours in a series of snapshots. Even with the shorter periods of analysis, the fit of the model is not as good as that reported in previous Dirichlet studies (Ehrenberg, 1994). The observed deviations from the model predictions include a tendency to overestimate the number of buyers (penetration) and to underestimate the purchase frequency and a consistent tendency to underestimate supplier loyalty. Partitioning of the market is evident in the ureteral and coronary stent cases with a segment of high frequency buyers dominating the observed purchase behaviours and resulting in the observed deviations. Such purchase frequency based segmentation has been noted previously (Bowman & Lele-Pingle, 1997) and may be regularity typical of industrial markets. When the NBD-Dirichlet model is operationalised using the heavy purchasing segment it accurately describes and predicts the observed purchasing patterns.

The research has also met the third objective to provide purchasing managers with metrics and benchmarks to assess and monitor buyer behaviour. The theoretical predictions of the NBD-Dirichlet model provide norms and benchmarks against which to assess current behaviours and to monitor the impact of interventions (Ehrenberg & Sharp, 2000). For example, in the ureteral stent case, buyers are more loyal to the two major suppliers than the model predicts. Such a deviation from the model benchmark suggests an opportunity for intervention and in the ureteral stent case a sustained promotional intervention results in loyalty performance much closer to the benchmark by the end of the three year analysis period. Similarly in the coronary stent case,

loyalty towards the dominant supplier is relatively constant and much higher than the Dirichlet benchmark until the implementation of the framework agreements after which it drops to levels much closer to the predicted norm.

9.4 Contribution

The research makes three main contributions to the literature. As a highly differentiated replication of the NBD-Dirichlet model, it extends the validity of this empirical generalisation. The research adds to the collaborative purchasing literature by demonstrating how the model can be applied in a collaborative purchasing context. In addition, the review of the literature also identifies unexpected common ground between the stochastic modelling and the Industrial Marketing and Purchasing (IMP) research traditions.

By extending the NBD-Dirichlet model into a complex collaborative public procurement context, the research represents a highly differentiated replication of the Dirichlet. Replication is an essential element in the development and testing of empirical generalisations, adding to the literature by extending generalisability to new conditions or by establishing boundary conditions where the model does not hold (Lindsay & Ehrenberg, 1993). This research demonstrates how violation of the Dirichlet assumptions of stationary behaviour and non-partitioned markets leads to deviations between the observed behaviours and the predicted Dirichlet norms.

The impact of purchasing framework agreements on buyer repertoires and observed loyalty behaviour is also discussed. Unrestrictive (i.e. many suppliers) agreements tend to increase use of smaller suppliers by establishing these

suppliers as credible alternatives. By contrast, restrictive agreements lead to restricted repertoires and an observed deviation of the Natural Monopoly Phenomenon (McPhee, 1963). The smallest suppliers would normally be expected to be purchased more frequently by the heaviest purchasers who have more opportunity to purchase and tend to be more experience purchasers. The observed patterns where restrictive frameworks are in place shows that the heaviest purchasers purchase almost exclusively from the market leading suppliers.

The collaborative purchasing literature deals mainly with the development and operation of purchasing consortia, rather than the buying behaviour of purchasers in such consortia (McCue & Prier, 2006). Extending the NBD-Dirichlet model into a collaborative purchasing context adds to the collaborative purchasing literature by providing new insights into buyer behaviour and a new way of describing and predicting buyer behaviour. The Dirichlet norms can be used as benchmarks to identify deviations from expected behaviours in order to identify opportunities for further research and to design and target purchasing interventions to change purchasing behaviours.

Using stochastic modelling to add context to network studies and to guide "purposeful sampling" (Dubois & Araujo, 2007) is one connection between stochastic modelling and the IMP or markets as networks research approach. Further common ground between these two traditions is explored in a paper published during the research and included in Appendix A (McCabe & Stern, 2009). This paper discusses shared assumptions about the nature of buyers, and the research objectives and methodologies employed. The current research is an

example of stochastic modelling techniques can be used "to study the proportion of newly established, continuing and disrupted relationships" (Gadde & Mattsson, 1987).

9.5 Summary

Growth in collaborative purchasing looks set to continue as organisations seek to pool their purchase requirements to deliver economies of scale, improve standardisation and increase leverage over suppliers. This is particularly so in public procurement where pooling large but typically fragmented purchase volumes is seen as a mechanism for delivering value for money under public expenditure constraints. However, for collaborative purchasing organisations to be effective, the behaviours of the member organisations must be managed to ensure compliance with purchasing framework agreements or to change purchasing behaviours.

It is important to understand what behaviours are exhibited before attempting to explain or change them. The research has shown that the steady-state NBD-Dirichlet model can be used to describe and interpret the dynamic changes in purchasing behaviours observed in the ureteral and coronary stent cases, providing a basis for identifying and monitoring subsequent interventions. Systematic deviations from the model are observed, including partitioning into heavy and light purchasing segments and excess loyalty resulting from buyer repertoires restricted by supplier framework agreements.

The research represents a substantial extension of the Dirichlet model into a complex collaborative public procurement context, further extending the

generalisability of the NBD-Dirichlet and applying it in the field of purchasing and supply chain management.

The research shows how the Dirichlet can improve understanding of purchasing patterns in collaborative purchasing environments in order to better target purchasing interventions and to monitor the progress of those interventions. Delivering sustainable cost savings through collaborative procurement arrangements requires established purchasing behaviours to change, for example to restrict supplier choice or to introduce new suppliers. Therefore it is important that purchasing managers understand how buyers are likely to react to these changes. Improved understanding leads to better design and monitoring of purchasing interventions and to increased savings from collaborative procurement activities.

Appendix A Stochastic Modelling and Industrial Networks - Complementary Views of Organisational Buyer Behaviour

A revised version of this paper was published in Journal of the Academy of Marketing Science.

McCabe, J. and Stern, P., (2009), 'Stochastic Modelling and Industrial Networks - Complementary Views of Organisational Buyer Behavior', *Journal of the Academy of Marketing Science*, 37 (2): 204-214.

Abstract

This paper investigates the common ground between two apparently contrasting approaches to the understanding of organizational purchasing behavior; stochastic modelling and the IMP (or "markets as networks") approach. These two schools of inquiry have travelled along parallel tracks for many years but there has never been a systematic attempt to analyse the ontological, epistemological and methodological similarities between them. We present a coherent theoretical framework to investigate the common ground between stochastic modelling and IMP and demonstrate that the two approaches offer complementary insights that can and should be exploited in the context of research into organizational purchasing behavior.

Introduction

"*They [customers] can be screaming for years, but they come back and buy the same machine off people [competitors]. And all they do is scream and bitch about them while you're there and then they go out and buy another one.*"

(Sales Executive, distributor of textile machinery, reported in Ellis and Hopkinson (2004), p. 18)

The business network research of the International Marketing and Purchasing (IMP) group reflected in the quote above is based on the observation of long-lasted inter-firm relationships (Hakansson, 1982; Gronroos, 1994; Ford & Hakansson, 2006). Buyers may have well-established and durable relationships with several suppliers of the same product or service. Changes in these relationships can be evolutionary, with new suppliers gradually taking a greater share of the buyer's purchases (Gadde & Mattsson, 1987; Dubois et al, 2003) or they may be discontinuous when an incumbent supplier is displaced by a competitor (Kamp, 2005).

Under these circumstances of single buyer – multiple suppliers, it is also important to understand the market structure within which the relationships are embedded in order to make sense of observed behaviours. Consider the quotation above; this could be an example of a stable long-term relationship between the incumbent supplier and the buyer. However, the interpretation of the observed behaviours and the subsequent analysis of the nature of the buyer-seller relationship should consider the prevailing market structure. A stable relationship in a market where buyers regularly switch between competing suppliers (who may all enjoy relationships with

the buyer) offers different research opportunities compared to such a relationship in a market where loyalty to a single source is the norm.

Stochastic theories of buyer behaviour provide this understanding of market structure (Ehrenberg, 1959; Goodhardt et al, 1984; Ehrenberg, 1995) in a way that can add context to studies of individual buyer-seller dyads or broader network analyses. For example, under NBD-Dirichlet theory (Goodhardt et al, 1984), switching brand or supplier is not viewed as instability or a change in buyer preference but rather as an expression of the stable probability that the buyer will purchase from a given supplier. This stable probability is itself an important dimension of the buyer-seller relationship and when considered together with the probabilities to purchase from other suppliers, it provides valuable insight into the competitive dynamics of the network. There has, however, been almost no analysis of repeat purchase patterns in organizational markets despite calls to use stochastic techniques "to study the proportion of newly established, continuing and disrupted relationships" (Gadde & Mattsson, 1987).

This paper starts to answer Gadde and Mattson's call demonstrating that stochastic modelling offers complementary insights to contemporary industrial network research. We present a coherent theoretical framework to draw out the ontological, epistemological and methodological common ground between stochastic modelling and IMP in a systematic way, providing a new contribution to the literature.

We show that stochastic modelling and IMP research traditions share important assumptions about the nature of buyers and sellers and their interactions. They share

an approach to knowledge creation that intertwines empirical observation and also theory development in an evolutionary process. Both traditions adopt an empirical approach to generalizability, employing multiple sets of data to establish that the observed and modelled patterns of behaviour can be replicated under different conditions or by seeking logical coherence through multiple sources of evidence. The implications for management are similar too, highlighting the constraints imposed on independent managerial action in a context of network interdependencies or apparent "as if random" behaviour.

These similarities are perhaps unexpected as there are some key areas of difference between the traditions. It is instructive to articulate these differences as a counterpoint to the similarities that we will develop in the body of the paper.

The first area of difference to consider is the theoretical foundation of each tradition. The fundamental assumptions underlying stochastic modelling (for example choice theory and bounded rationality) are very different from those utilised in the IMP approach (for example theories of power, resource dependence and actor/network theory).

Stochastic modelling is most often associated with consumer purchasing behaviour, a field of study that has traditionally been seen as distinct from organizational purchasing behavior (Wilson, 2000). In addition, while there have been instances of quantitative analysis in IMP research, qualitative approaches have traditionally predominated. In many cases one focal firm in an industry forms the case study in order to understand the network. This contrasts with stochastic modelling which

typically uses quantitative panel data covering a complete category to develop an understanding of the market structure.

The final difference highlighted here concerns the research objectives. Stochastic modelling provides norms and benchmarks against which managers can evaluate their market offerings whereas the IMP approach tends to provide a descriptive narrative which interprets the underlying causes determining the performance of network actors.

These are important differences but the similarities identified in this paper highlight an important message for researchers in both stochastic modelling and IMP. The two approaches complement each other and can and should be used together in the study of market networks to enhance understanding and prediction of organizational purchasing behaviour. This is in contrast to the tendency to compartmentalize each approach within a distinct and separate paradigm

The paper proceeds with a brief description of the background to the two approaches, highlighting the shared heritage of IMP and stochastic modelling. The key concepts of IMP and stochastic modelling are discussed and the traditions are compared in terms of their theoretical bases, research objectives, research methodology, core assumptions and research outputs. The paper concludes by highlighting the opportunities for the stochastic modelling and IMP approaches to complement each other and inform academic research and management practice in industrial marketing.

Background

Before embarking on a discussion of these traditions, it is useful to stop and consider what is meant by the terms "Stochastic Modelling" and "IMP Approach" as research traditions in the context of organizational purchasing behaviour. A general framework for comparison will be presented and will guide the subsequent discussion.

Stochastic Modelling

When it is impractical to include all relevant variables in an analysis or when variables may not be measured precisely, it is to be expected that no exact relationship will hold between the variables which can be measured. In such circumstances a stochastic relationship can be established by including one or more random variables described by a probability distribution (Arrow, 1968).

The stochastic modelling tradition in buyer behaviour research aims to describe the patterns of purchase before seeking to explain the observed behaviour. As Cunningham (1956) observes,

> *"… the why of brand loyalty behaviour can be effectively attacked by field interviewing only after we know its "what", "where" and "how much"".*

In the stochastic modelling tradition, observed regularities prompt the establishment of empirically grounded theory. The theory is tested more widely under different conditions to extend its generalizability and develop it conceptually. Ehrenberg (1994) has termed this approach "Empirical then Theoretical" (EtT) in contrast with

what he calls "Theoretical in Isolation" (TiI), the more traditional hypothetico-deductive approach where a theory is proposed and then tested empirically.

The Empirical then Theoretical (EtT) approach is described in typically parsimonious fashion (Ehrenberg, 1994).

(1) Establish a generalizable empirical pattern

(2) Develop a (low-level) theoretical model or explanation

Regularities in both purchase incidence and brand choice have been observed and documented in consumer and, less frequently, in organizational buyer behaviour research (Ehrenberg, 1959; Easton, 1980; Uncles & Ehrenberg, 1990; Stern & Ehrenberg, 1995; Pickford & Goodhardt, 2000). These regularities have been shown to occur over a wide range of purchase situations, product classes and time periods, to the extent that they become empirically generalizable, that is they become, "*a pattern or regularity that repeats over different circumstances and that can be described simply by mathematical, graphic or symbolic methods*" (Bass, 1995).

One such model is the NBD-Dirichlet, an integrated stochastic model of purchase incidence and brand choice that has been shown to explain and predict the law-like empirical patterns exhibited in repeat purchase behaviours (Goodhardt et al, 1984).

In the NBD-Dirichlet model, each buyer is assumed to have a certain probability of making a purchase of a product class and on each purchase occasion a certain probability of purchasing a particular brand. These probabilities vary across the population of buyers such that specific purchases occur in an apparently random

manner. This model has been shown to explain observed purchase behaviour in markets as diverse as coffee and aviation fuel, prescription drugs and television viewing choice (Uncles et al, 1995). Sharp et al. (2002) draw a distinction between repertoire and subscription markets and demonstrate that the NBD-Dirichlet model fits both types of market despite marked differences in purchase behaviour. In repertoire markets (typically observed with frequently purchased goods), on any given purchase occasion, buyers generally select one brand from a repertoire with a very low proportion of 100% loyalty to any particular brand. Subscription markets show much higher incidence of 100% loyal behaviour (Rundle-Thiele & Bennett, 2001) as buyers typically *subscribe* to a single supplier for an extended period. This type of behaviour can be seen in some service markets (for example credit card or utility supply services) and with infrequently purchased durable goods.

The NBD-Dirichlet theory links, explains and predicts several empirical generalizations concerning buying, including the Double Jeopardy effect whereby brands with low market share not only have fewer buyers but those buyers also buy the brand slightly less frequently than the buyers of bigger brands. Practical applications of the model include auditing the performance of established suppliers and assessing the effectiveness of marketing interventions (Ehrenberg & Sharp, 2000; Ehrenberg et al, 2004). A detailed description of the NBD-Dirichlet model and the range of empirical generalizations it yields is outside the scope of this paper but can be found in Goodhardt et al. (1984).

IMP Approach

Also known as the Industrial Networks or Markets-as-Networks approaches, the IMP tradition emphasizes the embeddedness and interconnectivity of the buyer-seller relationship, either as a dyad or within an extended network of relationships (Gadde & Mattsson, 1987; Ford, 2000). Mattsson (1997, p. 449) avoids a definition but describes "market processes as interactions within relationships and market structures as network structures".

The IMP group research is rooted in observation and empiricism. The initial study of almost 900 buyer-seller relationships across five European countries (Cunningham, 1980; Hakansson, 1982) was initiated from a perception that the then current theories of buying and selling behaviour did not adequately describe observed behaviours, in particular the importance of buyer-seller interaction in the context of long term relationships (Hakansson & Wootz, 1979).

This early inductive research sought to describe

> *"the pattern of dependencies between companies, the evolution of their dealings over time, the adaptations that each made to meet the requirements of the other party, and the inter-organizational person contact that took place" (Turnbull et al, 1996).*

Four key elements emerged from this study (Turnbull et al, 1996; Ford, 2004):

- buyers are heterogeneous and individually significant to their suppliers

- buyers and sellers interact to develop an offering which may be complex and highly adapted
- transactions are not isolated events but episodes embedded in a relationship where previous experiences and expectations have a significant impact
- Analysis of the selling or purchasing process independently of each other provides an inadequate explanation of what happened between buyers and sellers. The unit of analysis must be the relationship.

A discussion of the IMP research and the Interaction Model that developed from the research can be found in Håkansson (1982) and Cunningham (1980).

The networks approach has developed as the analysis moved beyond the buyer-seller dyadic relationship to consider the network of relationships within which a focal firm or individual relationship is located. The Actors – Activities – Resources (AAR) model is the primary analytical framework encountered in the study of industrial networks (Hakansson & Johanson, 1992). Actors are those who interact within relationships, perform activities and control resources. Activities refer to the combination, development, exchange or creation of resources by actors. Resources are the means by which actors carry out network activities. The AAR model has also been extended to recognize that the mental models (schemas, network pictures) held by individuals and organisations have a key role in the understanding of behaviour in networks (Welch & Wilkinson, 2002; Henneberg et al, 2006).

Comparison of Stochastic Modelling and IMP

Both Stochastic Modelling and IMP have long intellectual pedigrees, yet until now there has been no specific theoretical and managerial comparison between them, although a few researchers have called for the complementary practical application of both approaches. For example, in an early application of stochastic modelling in industrial markets (Easton, 1980) concluded that understanding the dynamics of industrial markets would add value to the study of organizational buying behaviour. Similarly Gadde and Mattson (1987) highlight the need for network level analyses to study sourcing strategies (many or few suppliers) and to identify any clustering of suppliers (i.e. which suppliers compete with which). While these papers suggest practical applications of stochastic modelling to inform the study of industrial networks, they do not present a coherent theoretical framework for the adoption of such a multi-methodological approach. Brennan (2006) provides such a comparison of evolutionary economics with the markets-as-networks tradition, and in particular the use of dynamic simulation modelling and historical studies to extend the understanding of industrial networks. However, in this analysis Brennan makes no mention of the rich tradition of stochastic modelling of buyer behaviour.

Framework for Comparison

Möller (1994) and Easton (1995a) both present frameworks for the metatheoretical analysis of different research traditions. They argue that any such framework should allow analysis of the ontological and epistemological basis for each tradition as it is the similarities or differences between these beliefs that will be the determinants of commensurability. The cognitive aims, the methods used and the disciplinary

foundations of the particular research tradition should also be assessed (Anderson, 1986). Assumptions concerning the nature of the market, of buyers and sellers and the nature of exchange will influence the comparison. Finally, the outputs of the research and the managerial implications can be considered (Mattsson, 1997).

Table 1 summarizes the comparison of the two traditions in terms of their disciplinary foundations, research objectives, research methodology, core assumptions and research outputs. These five dimensions are based on the framework used by Möller (1994) to carry out a comparison of transaction cost, political-economy, interaction and network approaches to interorganizational marketing exchange. The relation between the dimensions and Möller's framework is shown in the table.

Before considering in more detail the theoretical and methodological stances adopted by the stochastic modelling and IMP traditions it is instructive to consider the evolution of these schools of inquiry. Of course, shared experiences are no basis for seeking metatheoretical common ground but they do help in developing an understanding of the priorities and values of those who have advocated these approaches, often over periods of many decades.

	Stochastic Modelling	IMP Approach
Disciplinary Foundations [*Disciplinary background, Ontological assumptions and view of human nature (Moller, 1994)]*	Stochastic choice theory Bounded rationality Schumpeterian economics	Transaction costs theory Theories of power Resource dependence theory Social exchange theory Social network theory Relational contracting theory Contingency theory Actor/network theory New institutional economics
Research Objectives [*Theoretical emphasis, Basic goals, Driving force (Moller, 1994)]*	Descriptive Development of explanatory theory from empirical generalizations Predictive	Descriptive Exploratory Explanatory Interpretive
Research Methodology *[Methodological orientations, Research methods, Level and unit of analysis (Moller, 1994)]*		
a) Unit of Analysis	Purchase occasion	Relationship and Network
b) Mode of Analysis	Quantitative	Quantitative and Qualitative Mixed methods / Case study / Discourse Analysis
c) Data sources	Multiple, long term purchasing/sales records	Multiple interview, archival data; long term purchasing/sales records
d) Boundaries	Quasi closed system	Difficult to define network boundaries, open system
e) Measurement	Purchase occasion readily defined	Qualitative / Quantitative (survey, historical analysis)
f) Parsimony	Simple inputs	"Thick" descriptions complex and detailed
g) Testing	Replication	"Unassailability"
h) Predominant mode of inference	Inductive / Abductive	Inductive / Abductive
Core Assumptions *[Focus on structure vs process (Moller, 1994)]*		
a) Nature of Buying Organisations	Heterogeneous with regard to purchase incidence and supplier choice	Heterogeneous with regard to purchase incidence and supplier choice
b) Market Structure	Multiple interactions between buyers and suppliers with varying degrees of sole loyalty	Network entities active participants in buying process Multiple participants in buying process with varying degrees of independence and interdependence
c) Dynamics	Static short term, Dynamic long term	Static short term, Dynamic long term
d) Partitioning	Non-partitioned	Non-partitioned – customer as individual
e) Impact of previous buying decisions	Zero order	Non-zero order
f) Influences on Behaviour	Many and variable	Relationships (buyer-seller dyad) and other network relationships
Outputs and implications for marketing management [*Policy aims (Moller, 1994)]*	Flexible description of market structure Empirically grounded theory Norms and benchmarks	Descriptive narrative Causal mechanisms Interpretation Focus on managing relationships

Table 1 Comparison of Research Traditions

A shared heritage

There are many similarities between the paths taken by the IMP group and the Empirical-then-Theoretical tradition in stochastic modelling. Both traditions are rooted in empirical observation, with the research intended not to test a model but to lead to the formulation of a model (Cunningham, 1980). Both traditions have had to contend with being seen as "mere description" (Wensley, 1995; Rossiter, 1994). While this perception is commonly conflated with a perceived lack of normative prescription for management it should be noted that the NBD-Dirichlet model has demonstrated success in predicting and explaining many aspects of consumer behaviour using only penetration, purchase frequency and market share as inputs (Bhattacharya, 1997) as well as assisting decision making, notably in brand performance auditing, market partitioning, new brand planning and analysis of market dynamics (Ehrenberg & Sharp, 2000). Both traditions have also been forged in geographically concentrated, relatively tight-knit research communities that have had to fight to be heard within the marketing establishment (Ehrenberg, 1994; McLoughlin & Horan, 2002; Cova & Salle, 2003). Wensley (1995) introduces the "Ehrenberg" test to denote the avoidance of mention of stochastic modelling in marketing texts and identifies a similar absence of network thinking in these textbooks.

The comparison framework presented in Table 1 summarizes the challenges that IMP and Stochastic Modelling research posed to the contemporary theoretical approaches, in particular relating to the core assumptions about the market structure and the nature of participants in the market. These challenges echo the key findings of the initial IMP research (see Section IMP Approach), including a focus on the relationship rather than the discrete purchase; buyer-seller

interaction rather than isolated action by either buyer or seller; market participants as individually significant to each other rather than atomistic and able to be aggregated into homogeneous segments (Hakansson, 1982; Ford & Hakansson, 2006). The nature of these contrasting assumptions is developed further in the discussion section.

As research into markets and marketing has evolved, these challenges may not appear quite so clear cut as they did when the IMP group and Stochastic Modelling researchers were first struggling to make themselves heard. Relationship marketing has now been embraced by the marketing "establishment", hailing it as a "new paradigm" (Pine et al, 1995; Wensley, 1995). Individual learning relationships with customers explicitly recognize the individual significance of buyer and seller in a one to one relationship (Peppers et al, 1999). Cova and Salle (2003) highlight developments in consumer marketing, including the concept of tribes as groups forged by interdependence of their members (sounding rather like networks defined by interactions between actors) rather than homogeneous "segments".

However a key challenge to marketing orthodoxy remains. This has been described in "the myth of independence" and "the myth of action" (Ford et al, 2003). Buyers and sellers are interdependent and interact between themselves and with others in the network, often in unpredictable ways that constrain both managerial autonomy and the ability to act independently. As Ford and Håkansson (2006, p.250) put it:

> "*Interaction emphasises that the processes that occur between organisations are beyond the complete control of any individual actor.*

Interaction is not the outcome of the factors that drive a single action by a single actor. Instead, it is a process in which the effects of any action are affected by how that action is perceived and reacted to by the counterparts."

In a similar way the concept of "as if random" buying behaviour in the stochastic modelling tradition highlights the constraints on managers' ability to influence behaviours in steady markets. Many factors influence an individual purchase decision; certainly too many factors to model rigorously and in most cases, outside the marketing manager's control. Stochastic theories of behaviour accommodate this uncertainty by modelling purchase behaviour probabilistically (Goodhardt et al, 1984).

Discussion

Our contribution up to this point has been to demonstrate the developmental similarities between Stochastic Modelling and IMP traditions and to introduce the comparison framework. We now go further using Table 1 to highlight other key areas where the two approaches share common ground. These are summarized below and the arguments developed further in the following sections.

1. Disciplinary foundations
2. Research objectives
3. Research methodology
4. Core assumptions
5. Implications for marketing management

Disciplinary foundations

Stochastic modelling emphasizes the empirical in order to develop theoretical bases for observed behaviour. In the case of the NBD-Dirichlet, the theory states that the variation in purchase incidence (i.e. the number of purchases made by an individual purchaser in a specified time period) and the variation in vendor choice (i.e. the choices of supplier made by an individual purchaser each time they make a purchase) are of a steady state stochastic form (the Dirichlet). Theories to explain this stochastic behaviour have echoes of evolutionary economics (Brennan, 2006) with the importance of bounded rationality and decision rules (routines) based on satisficing rather than maximizing behaviour. In Dirichlet markets consumers are assumed to purchase from a *repertoire* of brands (bounded rationality) with fixed brand choice (routine).

IMP research draws on a number of disciplines and theoretical foundations including transaction cost theory, political science and theories of power, (inter-) organizational theory, resource dependence theory, social exchange and social network theory, behavioral theory, systems theory and relational contracting theory (Moller, 1994; Mattsson, 1997; Eiriz & Wilson, 2006; Mattsson & Johanson, 2006). Although this range of theoretical antecedents has been characterized as highlighting the "looseness" of much network research (Wensley, 1995), the alternative view of Brennan (2006) propounding the strength of intellectual flexibility demonstrated by the IMP tradition is more aligned with the views expressed here.

Research objectives

The primary objective in both Stochastic Modelling and IMP is to describe, interpret and explain observed regularities in buyer behaviour. Dubois and Gadde (2002) describe this as an abductive approach, starting with observation and developing descriptive and explanatory theory. Ehrenberg (1994) terms it Empirical then Theoretical (EtT). Just as the NBD-Dirichlet model was developed to describe the patterns observed repeatedly in consumer behaviour, so the Interaction and Actors-Activities-Resources (AAR) models were developed by the IMP group to describe the persistent long-term relationships observed in organizational behaviour. This data first approach may be criticised as being atheoretical but it is important to note that data is not collected independently of theory. Both Ehrenberg (1994) and Dubois and Gadde (2002) emphasize the creative nature of the scientific process where data and theory are interdependent. Observed regularities in the data prompt the establishment of empirically grounded theory. This theory is tested more widely under different conditions to extend the generalizability of the theory and to develop it conceptually.

This shared focus on empirically grounded theory also contributes to the common ground between the two schools of enquiry, setting them apart from research that is focused on developing and testing new theory (Barwise, 1995). Well established empirical generalisations that hold over many sets of data, across different populations and purchasing situations have tremendous predictive power and form a solid foundation for higher level theory and explanation.

This has happened with the IMP group as the study of markets as networks has evolved to become more explicitly explanatory and interpretive, studying interactions and relationships through the subjective interpretations of the actors (and researchers) (Ellis & Hopkinson, 2004). These developments can be seen as a natural progression towards deeper understanding, building on the work of the early IMP researchers while remaining within the IMP tradition. Similarly, the NBD-Dirichlet is now so well established that researchers can build on it by examining the nature of deviations from the expected norms (Bhattacharya, 1997).

Research methodology

We have already noted that the unit of analysis in the IMP research tradition is the relationship; understanding the interaction between buyer and seller over an extended series of "episodes". Stochastic modelling of repeat purchase behaviour also considers the temporal nature of the relationship and studies a subset of episodes, the occasions on which a buyer makes a purchase of a particular product. Rather than focusing on a single transaction, Stochastic Modelling and IMP focus on a longitudinal series of exchanges. This provides the opportunity to study the evolution of purchasing behaviour and the dynamic development of the network within which this behaviour occurs (Gadde & Mattsson, 1987; Dubois et al, 2003).

Easton (1995a) provides a useful overview of research methodologies for industrial networks, noting the difficulty of sampling the network for survey based research and the use of archival data (sales / purchasing records) for analysis of exchange links within networks. The predominant method of study

in IMP research has been interpretative through the medium of case studies (Easton, 1998) although there are notable instances of quantitative research in the IMP tradition. Indeed this analysis has been in part prompted by longitudinal studies considering the patterns of relationship activity around a focal firm (Gadde & Mattsson, 1987; Dubois et al, 2003; Kamp, 2005).

Generalizability is central to the process of knowledge creation and as such it is an important aspect of any comparative analysis of research traditions. Alternative research methodologies give rise to knowledge claims that can be seen as incommensurable. Blair and Zinkhan (2006) note three routes to generalizability; theoretical; probabilistic and empirical. We have already seen that Stochastic Modelling and IMP research both rely on empirical generalization – the extent to which the research findings can be replicated in different situations (products, countries, relationships). This approach requires multiple sources of evidence – Many Sets of Data (MSoD) (Ehrenberg, 1995). This is in contrast to much marketing research that adopts a probabilistic approach to generalizability, requiring representative samples and based on best fit statistical significance tested on a single set of data.

The generalizability of the single case study relies on the unassailability of the causal explanation of the observed phenomenon (Downward et al, 2002). However it is not clear what constitutes "unassailability". Easton (1998, p.81) suggests that the answer may lie in the way in which case research is conducted: "… to be inquisitive, to look for the roots of things, to disentangle complexities and to conceptualize and reconceptualise, test and retest, to be both rigorous and

creative and above all to seek for the underlying reality through the thick veil which hides it."

Easton himself has noted that this logic leads to multiple sources of evidence (data) (Easton, 1995a). It is perhaps a stretch too far to relate this to Ehrenberg's MsoD but there is a clear overlap with empirical generalization by replication with many sets of data. This is a distinct contrast with probabilistic generalization using single sets of data (SsoD).

Core assumptions

Both Stochastic Modelling and IMP start from the assumption that all customers are different. They differ in their frequency of purchase and they differ in their purchase choices. Both traditions identify constraints on the scope of managerial action to influence buyer behaviour, as a result of the interdependence between network actors or the "as if random" nature of purchase behaviour as described by the NBD- Dirichlet model.

The observation that many firms interacted in long-term durable relationships stimulated the empirical research programme in the early 1980s that would become the International Marketing and Purchasing (IMP) group (Hakansson, 1982; Ford & Hakansson, 2006). These researchers took the relationship between buyer and seller as the unit of analysis and viewed the purchase transaction as just one episode within an extended series of interactions. This approach identified buyers and suppliers as active participants in the purchasing process and recognised that in many cases organizational buyers are heterogeneous and individually significant to their suppliers (Hakansson, 1982; Gronroos, 1994; Ford & Hakansson, 2006).

In a similar way, stochastic theories of buyer behaviour developed from observations of unexpected regularities in consumer purchasing behaviour (Ehrenberg, 1988). The notion that consumer buying behaviour varies stochastically (i.e. as if at random) also challenges econometric models based on assumptions of optimising behaviour in rational consumers. A switch of supplier is not seen as a change in attitude, preference or perceived utility but as an expression of the stable probability that the buyer will purchase from a particular supplier. Like the IMP research, a stochastic modelling approach to the study of buyer behaviour assumes heterogeneity with respect to purchase incidence and brand choice across the population of consumers (heterogeneity that can be described by a probability distribution) and considers purchasing behaviours over a series of transactions (Ehrenberg, 1959; Goodhardt et al, 1984; Ehrenberg, 1995). The on-going propensities to purchase from specific suppliers over an extended period can be considered as defining aspects of the relationships between the buyer and seller(s).

Implications for marketing management

Both IMP and Stochastic Modelling highlight the difficulties of independent action by the marketing manager in a complex, self-organizing business network (Ritter et al, 2004). In NBD-Dirichlet markets, brands differ little in loyalty measures (purchase frequency, share of category requirements) even though market share and penetration usually vary greatly between brands. This implies that marketing interventions may affect penetration and market share but are likely to have little lasting effect on either loyalty or the buyer's ongoing purchase incidence and supplier choice probabilities (Ehrenberg et al, 2004). In

their analysis of the market for ready mixed concrete, Pickford and Goodhardt (2000) suggest that relationship marketing interventions (especially in industrial markets) ought to be focused on keeping the brand in the repertoire of split-loyal customers rather than used as a strategy for growth. In a similar way, IMP stresses that managerial independence is circumscribed by interaction between buyers and sellers and the extended network. This interdependence requires managers to understand the complexity and evolutionary nature of network relationships in order to maintain and develop their network position (Ford et al, 2003; Ritter et al, 2004).

The predictive power of stochastic models of buyer behaviour provides a quantitative context for analysis of the buyer seller relationship and of the interlocking network of relationships within which any individual transaction is made. The marketing manager can compare actual behaviour in the relationship against the probability of a repeat purchase being made. The likelihood of sole loyalty, when an organization fulfils all its requirements for a particular product from a single supplier, can be estimated and compared against observed levels of such behaviour (Ehrenberg et al, 2004). The expected repeat purchase probability is used as a benchmark to assess the effectiveness of customer retention or relationship strengthening interventions (Ehrenberg & Sharp, 2000). An analysis of buyer behavior using stochastic modelling techniques allows the account manager to estimate the expected probability of making a successful sale against an incumbent competitor. This is then be used to inform strategic decision-making, for example the selection of new markets and the mode of market entry.

If the frequency of purchase does not vary much between suppliers, then strategies to increase "share of wallet" by encouraging existing customers to buy more of the same product are unlikely to be successful. Companies wanting to grow in such markets would be well advised to focus on increasing market share by acquiring new customers and increasing penetration (Uncles & Ehrenberg, 1990).

How does the sales executive know that they are operating in a NBD-Dirichlet market? There is no industrial equivalent to the consumer panel data that has allowed the NBD-Dirichlet to be generalized across more than fifty different product categories. This points to a further implication for management – the need to systematically collect, analyse and share data and support research into patterns of buyer behaviour in organizational markets. As a preliminary step, the executive should ask why the market in which their company operates should deviate from Dirichlet norms.

Conclusions and implications for further research

Any comparative analysis of research traditions must pass the "so what" test. Is it a worthwhile comparison to make? In the case of stochastic modelling and IMP, we have shown that far from being stranded on either side of a spurious quantitative / qualitative divide, the two traditions have much in common. They share a common heritage; they share many assumptions about market structure and the scope for independent action by marketing managers; they have a shared objective in describing and explaining markets as they are. This paper presents a coherent theoretical framework to draw out the ontological, epistemological and methodological similarities between IMP and stochastic modelling.

A further test of relevance is to what extent this comparison adds to the understanding of markets. Using stochastic modelling to observe and model organizational behaviour gives market structure context to interaction and network studies. Easton (1992) notes that the extent to which actions are constrained by interdependence between members of the network will determine the extent to which behaviours are structured or stochastic. Less interdependence should mean less structure and more as-if-random behaviour. Campbell (1985) suggests that where transactions are infrequent, relationships are likely to be more independent. In the same way that dimensions of independence and interdependence have been used to describe organisational markets, consumer markets have been characterized as repertoire and subscription (Sharp et al, 2002). Consumers in repertoire markets purchase from a repertoire of brands, switch brands regularly and show low levels of "sole" loyalty. In subscription markets (e.g. credit cards, utility supplies), the levels of "sole" loyalty are much higher. Modelling of behaviour in different buying situations may expose repertoire and subscription behaviour in industrial markets, related to purchase frequency and the degree of interdependence between buyer and seller. If the nature of the relationship will differ between subscription and repertoire markets, so the study of the relationship should be informed by an understanding of the market structure.

The first direction for further research must be to establish to what extent models of purchasing behaviour such as the NBD-Dirichlet actually hold for organizational markets, especially low purchase frequency products such as capital equipment. This will require analysis of purchase behaviours for

different industrial markets over an extended period of time. As an example, the ideas in this paper are currently being developed into an empirical study that will assess the extent to which the NBD-Dirichlet holds in a range of organizational purchasing situations and whether these can be described as repertoire or subscription markets.

A second research direction will be to use stochastic analysis to determine the nature of the interactions within a relationship and to compare the interactions in competing relationships. Managing interactions in complex, self organizing relationships requires an understanding of relationship conditions such that managerial interventions are appropriate to the prevailing conditions in the relationship (Ritter et al, 2004). The opportunity to quantify and benchmark relationship "quality" will provide a parsimonious description of performance in a complex business network and will be useful measure against which to judge the effectiveness of management action, to isolate the interventions that may be determinants of relationship quality and to predict the impact of proposed interventions.

The establishment of generalizations about the behaviour of firms, relationships and networks also lays a foundation for the construction of simulation models, another potential research direction for researchers into inter-organisational behaviour in complex business networks (Wilkinson & Young, 2005). Agent based models simulate how networks and structures arise from individual behaviors and may be used to investigate how regular patterns such as those described by the NBD-Dirichlet come about or they can use those regular patterns to model behaviours in the simulation. Such models become effective

tools for experimental research, for teaching and learning and for decision making.

By combining the approaches in this way, the IMP tradition gains from insights into market structure and stochastic modelling gains from a rich contextual framework to make sense of the observed patterns and regularities. The use of descriptive statistics to identify patterns that guide subsequent sociological research has a long and distinguished history, stretching from Durkheim's classic research on suicide in the late nineteenth century (Benton & Craib, 2001; Mingers, 2003). An example of this complementarity is provided by Gadde and Mattsson (1987) who propose a longitudinal analysis similar to the repeat buying analysis carried out on consumer panel data in order to describe stability and change in network relationships – "to study the proportion of newly established, continuing and disrupted relationships". Their aim is exploratory; the language could be Ehrenbergian (new buyers, repeat buyers, lapsed buyers) – the approach is EtT.

Appendix B Abbreviations and Notation

AAR	Actors Activities Resources
B2B	Business to Business
B2C	Business to Consumer
BG-NBD	Beta Geometric Negative Binomial Distribution
BMS	Bare Metal Stent
C2C	Consumer to Consumer
CCT	Compulsory Competitive Tendering
CEP	Centre for Evidence-Based Purchasing
CLV	Customer Lifetime Value
CMU	Commercial Medicines Unit
CNBD	Condensed Negative Binomial Distribution
CPH	Collaborative Procurement Hub
CRiSPS	Centre for Research in Strategic Purchasing and Supply
CSU	Commercial Support Unit
DCA	Discrete Choice Analysis
DES	Drug Eluting Stent
EtT	Empirical then Theoretical
FDD	Frequency Dependent Dirichlet
GP	General Practitioner
IMP	Industrial Marketing and Purchasing
MAD	Mean Absolute Deviation
MBG-NBD	Modified Beta Geometic Negative Binomial Distribution
MLH	Maximum Likelihood Hierarch
NBD	Negative Binomial Distribution
NHS	National Health Service
NICE	National Institute of Clinical Excellence
O	Observed Values (used in Tables)
OGC	Office of Government Commerce
OGCbs	Office of Government Commerce buying solutions
PASA	Purchasing and Supply Agency
PCT	Primary Care Trust
SCEP	Supply Chain Excellence Programme
SCR	Share of Category Requirements
SHA	Strategic Health Authority
T	Theoretical Values (used in Tables)
TiI	Theoretical in Isolation
VCT	Voluntary Competitive Tendering

Selected mathematical notation used in the thesis

B	Category Penetration
b	Individual Supplier Penetration
D_{XY}	Duplication Coefficient
k	Exponent of the NBD
M	Average number of purchases of the category per individual
m	Average number of purchases of a particular supplier per individual ($m = b \times w$)
p_r	Probability of making r purchases (where r is a non-negative integer)
$p_{r\|n}$	Probability of making r purchases of a supplier, conditional on making n purchases of the category
S	Dirichlet switching parameter
T	Time period based on base period for analysis
W	Category Purchase Frequency
w	Individual Supplier Purchase Frequency
α	Beta distribution parameter
α	Beta distribution parameter
μ	Long run average purchase frequency (Poisson mean)

Appendix C Interview Questions and Transcript

Outline for CPH meeting

1. Introduction – background. What is Dirichlet. How is it used
2. Data – what was analysed & how was it done
3. Findings
4. Ureteral stents – show market share chart and identify transitions
5. Each period show penetration / PF, SCR numbers for whole population & heavy population.
6. Show duplication of purchase (whole population & heavies)
7. Conclusions – identify scope for intervention, track progress. New buyers. Duplications. Supplier development. Penetration vs Frequency. Contingent factors (growth)

Questions

1. Does dataset include supplies for private treatments?
2. Nature of interventions in 2006/7 – reduce supply base, preferred (only) supplier agreements, price/volume based
3. How these sustained – evidence of creep back in coronary stent data
4. Extent of reporting
5. Nature of cost centres – high volume "standardised" vs low volume variable. What about teaching / research / variety seeking?
6. What interventions were made w.r.t. Cook in 2007 / 2008
7. Conscious decision to "turn" heavy purchasers?
8. New entrants – actual new entrants or changes in reporting population?
9. Increase in purchase frequency (Cook) in 2007?

Interview Transcript (extract) 7 October 2010

Rachel
'we had to spend quite a significant amount of time in getting the engagement with our customers and also with the suppliers before we actually formerly go to tender'

JMcC
'yeah'

Rachel
'so we could spend up to a year talking to trusts about how we are going to structure this, what they want to get out of it, what levels of commitment are we talking about and then on the supplier side it's important that they understand what we are trying to achieve so that they're in a position so they can submit their best offers'

JMcC
'yeah'

Rachel
so we need them to understand not only the objective but who's involved and why are we doing it and what our expectations are'

JMcC
'yeah'

Rachel
'so we do all of that up front so that when we go to tender it's not a surprise they are all who expecting it and we awarded the framework August 08 so that was when the prices under the framework commenced but we had seen some movement before then, cause what you find is when you start to talk to suppliers and start to talk to customers about the fact that we are going to do a project you immediately start to see prices change'

JMcC
'yeah'

Rachel
'because people / the suppliers are trying to get trust commitment and trying to undermine the process and so our stake in the ground - previous price paid you only start the project like in 2007 because then you start to influence the market and you start to see fluctuation and the prices do drop'

JMcC
yeah, and was that early 2007?'

Rachel
'it would probably /it would have been mid to late because the award was in August so we would have started that probably September / October time'

‘yeah, ok’ ‘so it would be interesting to see in terms of your data what was happening around then’

JMcC
‘right’

Rachel
‘and then we awarded the framework in August 08 and we’ve delivered about three million pounds worth of savings to date since then’

JMcC
‘just in the cardiac?’

Rachel
‘yes just on stents and cath lab consumerables and we have just negotiated a twelve month extension on that and got further savings’

JMcC
yeah’

Rachel
‘yeah so it’s been very successful.

JMcC
‘interesting, so three millions savings from August 08’

Rachel
‘yeah’

JMcC
‘the data I looked at goes upto March 09 so I can only see a little bit of that but there’s been a lot of activity before that’

Rachel
‘I can imagine’

JMcC
‘so it could be interesting to look at that and before the project started did individual trusts have their own agreements with suppliers’

Rachel
‘yeah individuals trusts would have negotiated locally and would have had individual contracts in place and there would have been discussion across the cardiac network about prices I’m sure, because cardiac networks do look at the commercial aspects as well as the clinical side and / but no there would have been a lot of disparity in prices across the trusts’

JMcC
‘yes’

Rachel
'hugely'

JMcC
'yeah and was there any terms in the decision making in terms of which suppliers to use or any guidance or / I presuming that would have been discussed in the cardiac network….'

Rachel
'yeah that's where the network come in, the consultants individually have ultimate decision over what they can use which might not necessarily be the right course of action but the network do come together and they do talk about what they each use and that has generated some standardisation just through those discussions but they each have the decision over what happens, our role is to provide evidence that alternatives are clinically acceptable and it's for them to assess whether that evidence is accurate and to discuss with us whether it's / whether they could change'

JMcC
'yeah'

Rachel
'so we kind of do the commercial analysis and they help us do the clinical assessment'

References

Anderson, J. C., Hakansson, H. and Johanson, J. (1994) Dyadic Business Relationships Within a Business Network Context. *Journal of Marketing*, 58 (4): 1-15.

Anderson, M. G. and Katz, P. B. (1998) Strategic Sourcing. *International Journal of Logistics Management*, 9 (1): 1-13.

Anderson, P. F. (1986) On Method in Consumer Research: A Critical Relativist Perspective. *Journal of Consumer Research*, 13 (September): 155-173.

Anderson, P. F. and Chambers, T. M. (1985) A Reward / Measurement Model of Organizational Buying Behavior. *Journal of Marketing*, 49 (Spring): 7-23.

Anonymous (2009a) *Annual Report 2008/2009*.

Anonymous (2009b) *Report to the Trust Board*.

Arrow, K. J. (1968) Mathematical Models in the Social Sciences. In: Brodbeck, M. eds. *Readings in the Philosophy of the Social Sciences*. New York: Macmillan: 635-667.

Autry, C. W. and Golicic, S. L. (2010) Evaluating Buyer-Supplier Relationship-Performance Spirals: A Longitudinal Study. *Journal of Operations Management*, 28 (2): 87-100.

Bakker, E. and Walker, H. (2008) Collaborative Procurement in Local Government. *Centre for Research in Strategic Purchasing and Supply*, Univeristy of Bath School of Management.

Bakker, E., Walker, H. and Harland, C. (2006a) Organising for Collaborative Procurement:An Initial Conceptual Framework. In: Thai, K. and Piga, G. eds. *Advancing Public Procurement: Practices, Innovation and Knowledge-Sharing*. Boca Raton, FL: Academic Press: 14-44.

Bakker, E., Walker, H., Harland, C. and Warrington, J. (2006b) The Effect of Collaborative Purchasing Structures on Managing Cooperation. *Proceedings of the 15th Annual IPSERA Conference*, San Diego (United States).

Baldinger, A. L. and Rubinson, J. (1997) In Search of the Holy Grail: A Rejoinder. *Journal of Advertising Research*, 37 (1): 18-20.

Barclay, D. W. (1992) Organizational Buying Outcomes and Their Effects on Subsequent Decisions. *European Journal of Marketing*, 24 (4): 48-64.

Barwise, P. (1995) Good Empirical Generalizations. *Marketing Science*, 14 (3): G29-G35.

Bass, F. M. (1969) A New Product Growth Model for Consumer Durables. *Management Science*, 15 (January): 215-227.

Bass, F. M. (1974) The Theory of Stochastic Preference and Brand Switching. *Journal of Marketing Research*, 11 (February): 1-20.

Bass, F. M. (1995) Empirical Generalizations and Marketing Science: A Personal View. *Marketing Science*, 14 (3 Part 2 of 2): G6-G19.

Bass, F. M., Jeuland, A. and Gordon P. Wright (1976) Equilibrium Stochastic Choice and Market Penetration Theories: Derivations and Comparisons. *Management Science*, 22 (10): 1051-1063.

Bass, F. M. and Pilon, T. L. (1980) A Stochastic Brand Choice Framework for Econometric Modeling of Time Series Market Share Behavior. *Journal of Marketing Research*, 17 (4): 486-497.

Bass, F. M. and Wind, J. (1995) Introduction to the Special Issue: Empirical Generalizations in Marketing. *Marketing Science*, 14 (3 Part 2 of 2): G1-G5.

Batislam, E. P., Denizel, M. and Filiztekin, A. (2007) Empirical Validation and Comparison of Models for Customer Base Analysis. *International Journal of Research in Marketing*, 24 (3): 201-209.

Beamon (1998) Supply Chain Design and Analysis: Models and Methods. *International Journal of Production Economics*, 55 (3): 281-294.

Bemmaor, A. (1994) Commentary on "Theory or Well-Based Results: Which Comes First?". In: Laurent, G., Lilien, G. L. and Pras, B. eds. *Research Traditions in Marketing*. Dordrecht: Kluwer Academic Publishers: 109-115.

Bennett, R., Hartel, C. E. J. and McColl-Kennedy, J. R. (2005) Experience as a Moderator of Involvement and Satisfaction on Brand Loyalty in a Business-to-Business Setting. *Industrial Marketing Management*, 34 (1): 97-107.

Bensaou, M. (1999) Portfolios of Buyer-Supplier Relationships. *Sloan Management Review*, 40 (Summer): 35-44.

Benton, T. and Craib, I. (2001) *Philosophy of Social Science*. Basingstoke: Palgrave.

Bhattacharya, C. B. (1997) Is Your Brand's Loyalty Too Much, Too Little, or Just Right?: Explaining Deviations in Loyalty From the Dirichlet Norm. *International Journal of Research in Marketing*, 14 (5): 421-435.

Biemans, W. G. and Brand, M. J. (1995) Reverse Marketing: A Synergy of Purchasing and Relationship Management. *International Journal of Purchasing and Materials Management*, 31 (3): 29-37.

Blair, E. and Zinkhan, G. (2006) Nonresponse and Generalizability in Academic Research. *Journal of the Academy of Marketing Science*, 34 (1): 4-7.

Bonner, J. M. and Calantone, R. J. (2005) Buyer Attentiveness in Buyer-Supplier Relationships. *Industrial Marketing Management*, 34 (1): 53-61.

Bowman, D. and Lele-Pingle, S. (1997) Buyer Behavior in Business-to-Business Services: The Case of Foreign Exchange. *International Journal of Research in Marketing*, 14 (5): 499-508.

Brand, M. J. and Leeflang, P. S. H. (1994) Research on Modeling Industrial Markets. In: Laurent, G., Lilien, G. L. and Pras, B. eds. *Research Traditions in Marketing*. Boston/Dordrecht/London: Kluwer Academic Publishers: 231-261.

Brennan, R. (2006) Evolutionary Economics and the Markets-as-Networks Approach. *Industrial Marketing Management*, 35 (7): 829-838.

Brinkmann, J. and Voeth, M. (2007) An Analysis of Buying Center Decisions Through the Salesforce. *Industrial Marketing Management*, 36 (7): 998-1009.

Bubb, P. L. and van Rest, D. J. (1973) Loyalty as a Component of the Industrial Buying Decision. *Industrial Marketing Management*, 3 (1): 25-32.

Burke, G., J., Carrillo, J. E. and Vakharia, A. J. (2007) Single versus Multiple Supplier Sourcing Strategies. *European Journal of Operational Research*, 182 (1): 95-112.

Caldwell, N., Walker, H., Harland, C., Knight, L., Zheng, J. and Wakely, T. (2005) Promoting Competitive Markets: The Role of Public Procurement. *Journal of Purchasing & Supply Management*, 11 (5 - 6): 242-251.

Campbell, N. C. G. (1985) An Interaction Approach to Organizational Buying Behavior. *Journal of Business Research*, 13 (1): 35-48.

Chapman, T. L., Gupta, A. and Mango, P. D. (1998) Group Purchasing is not a Panacea for US Hospitals. *The McKinsey Quarterly*, 1998 (1): 160-165.

Chatfield, C. and Goodhardt, G. (1975) Results Concerning Brand Choice. *Journal of Marketing Science*, XII (February): 110-113.

Chatfield, C. and Goodhardt, G. J. (1970) The Beta-Binomial Model for Consumer Purchasing Behaviour. *Journal of the Royal Statistical Society. Series C (Applied Statistics)*, 19 (3): 240-250.

Chatfield, C. and Goodhardt, G. J. (1973) A Consumer Purchasing Model with Erlang Inter-Purchase Time. *Journal of the American Statistical Association*, 68 (344): 828-835.

Cheung, M. Y. S. and Turnbull, P. W. (1998) A Review of the Nature and Development of Inter-Organisational Relationships: A Network Perspective. In: Naude, P. and Turnbull, P. W. eds. *Network Dynamics in International Marketing*. Oxford: Elsevier Science: 42-69.

Choffray, J.-M. and Lilien, G. L. (1978) Assessing Response to Industrial Marketing Strategy. *Journal of Marketing*, 42 (2): 20-31.

Cleverley, W. O. and Nutt, P. C. (1984) The Effectiveness of Group-Purchasing Organizations. *Health Services Research*, 19 (1): 65-81.

Cohen, A. (2002) Strength in Numbers. *Supply Management*, 7 (5): 28-29.

Costantino, N. and Pellegrino, R. (2010) Choosing between Single and Multiple Sourcing Based on Supplier Default risk: A Real Options Approach. *Journal of Purchasing & Supply Management*, 16 (1): 27-40.

Cousins, P. D. (1999) Supply Base Rationalisation: Myth or Reality? *European Journal of Purchasing & Supply Management*, 5 (3-4): 143-155.

Cova, B. and Salle, R. (2003) When IMP-Don Quixote Tilts his Lance Against the Kotlerian Windmills: BtoB Marketing Deeply Changed Dring the Last 25 Years, BtoC Marketing Too. *Proceedings of the 19th Annual IMP Conference*, Lugano, Switzerland.

Cox, A., Chicksand, D. and Ireland, P. (2005) Sub-Optimality in NHS Sourcing in the UK: Demand-Side Constraints on Supply-Side Improvement. *Public Administration*, 83 (2): 367-392.

Croom, S. and Brandon-Jones, A. (2007) Impact of e-Procurement: Experiences from Implementation in the UK Public Sector. *Journal of Purchasing & Supply Management*, 13 (4): 274-293.

Cunningham, M. T. (1980) International Marketing and Purchasing of Industrial Goods - Features of a European Research Project. *European Journal of Marketing*, 14 (5/6): 322-328.

Cunningham, M. T. and Kettlewood, K. (1976) Source Loyalty in the Freight Transport Market. *European Journal of Marketing*, 10 (1): 60-79.

Cunningham, R. (1956) Brand Loyalty - What, Where, How Much? *Harvard Business Review*, 1956 (34): 116-128.

Dacko, S., G. (2008) *The Advanced Dictionary of Marketing: Putting Theory to Use*. Oxford: Oxford University Press.

Dall'Olmo Riley, F., Ehrenberg, A. S. C., Castleberry, S. B., Barwise, T. P. and Barnard, N. R. (1997) The Variability of Attitudinal Repeat-Rates. *International Journal of Research in Marketing*, 14 (5): 437-450.

de Belder, M. A. (2008) NICE Guidelines For the Use of Drug-Eluting Stents: How Do We Establish Worth? *Heart*, 94 (12): 1646-1652.

Department of Health (2009a) *The Statement of NHS Accountability*. [online] Available from: http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_093418.pdf (Accessed 27 September 2010).

Department of Health (2009b) *Necessity - not Nicety*. [online] Available from: http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_098874.pdf (Accessed 26 September 2010).

Department of Health (2009c) *Departmental Report 2009*. [online] Available from: http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_100819.pdf (Accessed 27 September 2010).

Department of Health (2010a) *Commercial Skills for the NHS*. [online] Available from: http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_113744 (Accessed 1/12/2010).

Department of Health (2010b) *The NHS Constitution*. [online] Available from: http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_113613 (Accessed 26 September 2010).

Dick, A. S. and Basu, K. (1994) Customer Loyalty: Toward an Integrated Conceptual Framework. *Journal of the Academy of Marketing Science*, 22 (2): 99-113.

Dillon, W. R. and Gupta, S. (1996) A Segment-Level Model of Category Volume and Brand Choice. *Marketing Science*, 15 (1): 38-59.

Doucette, W. R. (1997) Influences on Member Commitment to Group Purchasing Organizations. *Journal of Business Research*, 40 (3): 183-189.

Downward, P., Finch, J. H. and Ramsay, J. (2002) Critical Realism, Empirical Methods and Inference: A Critical Discussion. *Cambridge Journal of Economics*, 26 (4): 481-500.

Doyle, P. (1995) Marketing in the New Millennium. *European Journal of Marketing*, 29 (13): 23-41.

Dubois, A. and Araujo, L. (2007) Case Research in Purchasing and Supply Management: Opportunities and Challenges. *Journal of Purchasing & Supply Management*, 13 (3): 170-181.

Dubois, A. and Gadde, L.-E. (2002) Systematic Combining: An Abductive Approach to Case Research. *Journal of Business Research*, 55 (7): 553-560.

Dubois, A., Gadde, L.-E. and Mattsson, L.-G. (2003) Change and Continuity in the Supplier Base: A Case Study of a Manufacturing Firm 1964-2002. *Journal of Customer Behaviour*, 2 (3): 409-432.

Dunn, R., Reader, S. and Wrigley, N. (1983) An Investigation of the Assumptions of the NBD Model as Applied to Purchasing at Individual Stores. *Applied Statistics*, 32 (3): 249-259.

Dwyer, F. R., Schurr, P. H. and Oh, S. (1987) Developing Buyer-Seller Relationships. *Journal of Marketing*, 51 (2): 11-27.

Easton, G. (1980) Stochastic Models of Industrial Buying Behaviour. *Omega*, 8 (1): 63-69.

Easton, G. (1992) Industrial Networks: A Review. In: Axelsson, B. and Easton, G. eds. *Industrial Networks: A new View of Reality*. London: Routledge: 3-27.

Easton, G. (1995a) Methodology and Industrial Networks. In: Moller, K. and Wilson, D. eds. *Business Marketing: An Interaction and Network Perspective*. Norwell USA: Kluwer Academic Publishers: 411-491.

Easton, G. (1995b) Comments on Wensley's "A Critical Review of Marketing: Market Networks and Interfirm Relationships". *British Journal of Management*, 6 (December): S83-S86.

Easton, G. (1998) Case Research as a Methodology for Industrial Networks; A Realist Apologia. In: Naude, P. and Turnbull, P. W. eds. *Network Dynamics in International Marketing*. Oxford: Elsevier Science: 73-87.

Easton, G. and Araujo, L. (1986) Networks, Bonding and Relationships in Industrial Markets. *Industrial Marketing and Purchasing*, 1 (1): 8-25.

Ehrenberg, A. (1997) In Search of Holy Grails: Two Comments. *Journal of Advertising Research*, 37 (1): 9-12.

Ehrenberg, A. and Sharp, B. (2000) Managerial Uses of Descriptive Marketing Models - The Case of the Dirichlet. *ANZMAC 2000 Visionary Marketing for the 21st Century: Facing the Challenge*, Gold Coast, Queensland, Australia 296-301.

Ehrenberg, A. S. C. (1959) The Pattern of Consumer Purchases. *Applied Statistics*, 8 (1): 26-41.

Ehrenberg, A. S. C. (1988) *Repeat-Buying: Facts, Theory and Applications*. London: Edward Arnold (Griffin).

Ehrenberg, A. S. C. (1991) New Brands and the Existing Market. *Journal of the Market Research Society*, 33 (4): 285-299.

Ehrenberg, A. S. C. (1994) Theory or Well-Based Results: Which Comes First? In: Laurent, G., Lilien, G. L. and Pras, B. eds. *Research Traditions in Marketing*. Boston/Dordrecht/London: Kluwer Academic Publishers: 79-105.

Ehrenberg, A. S. C. (1995) Empirical Generalisations, Theory, and Method. *Marketing Science*, 14 (3 Part 2 of 2): G20-G28.

Ehrenberg, A. S. C. and Bound, J. A. (1993) Predictability and Prediction. *Journal of the Royal Statistical Society A*, 156 (2): 167-206.

Ehrenberg, A. S. C., Hammond, K. and Goodhardt, G. J. (1994) The After-Effects of Price-Related Consumer Promotions. *Journal of Advertising Research*, 34 (4): 11-21.

Ehrenberg, A. S. C., Uncles, M. D. and Goodhardt, G. J. (2004) Understanding Brand Performance Measures: Using Dirichlet Benchmarks. *Journal of Business Research*, 57 (12): 1307-1325.

Eiriz, V. and Wilson, D. (2006) Research in Relationship Marketing: Antecedents, Traditions and Integration. *European Journal of Marketing*, 40 (3/4): 275-291.

Elberse, A. (2007) A Taste for Obscurity? An Individual-Level Examination of "Long Tail" Consumption. *Harvard Business School Working paper No. 08-008*, August 2007.

Elhauge, E. (2002) *The Exclusion of Competition for Hospital Sales through Group Purchasing Organizations*. [online] Available from: http://www.law.harvard.edu/faculty/elhauge/pdf/gpo_report_june_02.pdf (Accessed 2 November 2010).

Ellis, N. and Hopkinson, G. (2004) Talking of Talk ... Does it Matter? *Proceedings of the 20th Annual Conference of the Industrial Marketing and Purchasing Group*, Copenhagen.

Emberson, C. and Storey, J. (2006) Buyer-Supplier Collaborative Relationships: Beyond the Normative Accounts. *Journal of Purchasing & Supply Management*, 12 (5): 236-245.

Essig, M. (2000) Purchasing Consortia as Symbiotic Relationships: Developing the Concept of "Consortium Sourcing". *European Journal of Purchasing and Supply Management*, 6 (1): 13-22.

Fader, P., S., Hardie, B., G. S. and Lee, K. L. (2005) "Counting Your Customers" the Easy Way: An Alternative to the Pareto/NBD Model. *Marketing Science*, 24 (2): 275-284.

Fader, P. S. and Schmittlein, D. C. (1993) Excess Behavioral Loyalty for High-Share Brands: Deviations from the Dirichlet Model for Repeat Purchasing. *Journal of Marketing Research*, 30 (November): 478-493.

Fern, E. F. and Brown, J. R. (1984) The Industrial/Consumer Marketing Dichotomy: A Case of Insufficient Justification. *The Journal of Marketing*, 48 (2): 68-77.

Ford, D. (2000) *Understanding Business Markets: Interaction, Relationships and Networks*. London: Thomson Learning.

Ford, D. (2004) The IMP Group and International Marketing. *International Marketing Review*, 21 (2): 139-141.

Ford, D., Gadde, L.-E., Hakansson, H. and Snehota, I. (2003) *Managing Business Relationships*. Chichester: John Wiley.

Ford, D. and Hakansson, H. (2006) IMP - Some Things Achieved: Much More to Do. *European Journal of Marketing*, 40 (3/4): 248-258.

Ford, D., Hakansson, H. and Johanson, J. (1986) How do Companies Interact? *Industrial Marketing and Purchasing*, 1 (1): 26-41.

Frohlich, M. T. and Dixon, J. R. (2006) Reflections on Replication in OM Research and this Special Issue. *Journal of Operations Management*, 24 (6): 865-867.

Gadde, L.-E. and Mattsson, L.-G. (1987) Stability and Change in Network Relationships. *International Journal of Research in Marketing*, 4 (1): 29-41.

Galloway, M. (2009) *The ACP Guide to the Structure of the NHS in the United Kingdom*. [online] Available from: http://www.pathologists.org.uk/publications-page/NHS10.pdf (Accessed 27 September 2010).

Gee, R., Coates, G. and Nicholson, M. (2008) Understanding and Profitably Managing Customer Loyalty. *Marketing Intelligence & Planning*, 26 (4): 359-374.

Gensch, D. H. (1987) A Two-Stage Disaggregate Attribute Choice Model. *Marketing Science*, 6 (3): 223-239.

Gershon, P. (2004) *Releasing Resources to the Front Line, Independent Review of Public Sector Efficiency*. [online] Available from: http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/d/efficiency_review120704.pdf (Accessed 27 September 2010).

Goodhardt, G. J., Ehrenberg, A. S. C. and Chatfield, C. (1984) The Dirichlet: A Comprehensive Model of Buying Behaviour. *Journal of the Royal Statistical Society*, 147 (5): 621-655.

Gronroos, C. (1994) Quo Vadis, Marketing? Toward a Relationship Marketing Paradigm. *Journal of Marketing Management*, 10 347-360.

Guadagni, P. M. and Little, J. D. C. (1983) A Logit Model of Brand Choice Calibrated on Scanner Data. *Marketing Science*, 2 (3): 203-238.

Gummesson, E. and Polese, F. (2009) B2B is not an Island! *Journal of Business & Industrial Marketing*, 24 (5/6): 337-350.

Hahn, C. K., Kim, K. H. and Kim, J. S. (1986) Costs of Competition: Implications for Purchasing Strategy. *Journal of Purchasing and Materials Management*, 22 (3): 2-7.

Hakansson, H. (1982) *International Marketing and Purchasing of Industrial Goods*. Chichester: John Wiley.

Hakansson, H. and Johanson, J. (1992) A Model of Industrial Networks. In: Axelsson, B. and Easton, G. eds. *Industrial Networks: A New View of Reality*. London: Routledge: 28-34.

Hakansson, H. and Snehota, I. (1998) The Burden of relationships or Who's Next. In: Naude, P. and Turnbull, P. W. eds. *Network Dynamics in International Marketing*. Oxford: Elsevier Science: 16-25.

Hakansson, H. and Wootz, B. (1979) A Framework of Industrial Buying and Selling. *Industrial Marketing Management*, 8 (1): 28-39.

Hallen, L., Johanson, J. and Seyed-Mohamed, N. (1991) Interfirm Adaptation in Business Relationships. *Journal of Marketing*, 55 (2): 29-37.

Harland, C., Bakker, E., Caldwell, N., Phillips, W. and Walker, H. (2005) The Changing Role of Public Procurement - Executive Report from the Second International Research Study of Public Procurement. *Centre for Research in Strategic Purchasing and Supply*, University of Bath School of Management.

Harland, C., Rudd, A., Knight, L., Forrest, S. and Bakker, E. (2007) Procurement in the English National Health Service. In: Knight, L., Harland, C., Telgen, J., Thai, K. V., Callender, G. and McKen, K. eds. *Public Procurement. International cases and commentary*. Abingdon, Oxon: Routledge: 42-59.

Heide, J. B. and Weiss, A. M. (1995) Vendor Consideration and Switching Behavior for Buyers in High-Technology Markets. *Journal of Marketing*, 59 (3): 30-43.

Hendrick, T. E. (1997) Purchasing Consortiums: Horizontal Alliances Among Firms Buying Common Goods and Services. *CAPS Report*, Tempe.

Henneberg, S. C., Mouzas, S. and Naude, P. (2006) Network Pictures: Concepts and Representations. *European Journal of Marketing*, 40 (3/4): 408-429.

Hunt, S. D. (1983) General Theories and the Fundamental Explananda of Marketing. *Journal of Marketing*, 47 (4): 9-17.

Jacoby, J. (1971) A Model of Multi-Brand Loyalty. *Journal of Advertising Research*, 11 (3): 25-31.

Jarvis, L. P. and Wilcox, J. B. (1977) True Vendor Loyalty or Simply Repeat Purchase Behavior? *Industrial Marketing Management*, 6 (1): 9-14.

Jeuland, A. P., Bass, F. M. and Wright, G. P. (1980) A Multibrand Stochastic Model Compounding Heterogeneous Erlang Timing and Multinomial Choice Processes. *Operations Research*, 28 (2): 255-277.

Johnson, P. F. (1999) The Pattern of Evolution in Public Sector Purchasing Consortia. *International Journal of Logistics: Research and Applications*, 2 (1): 57-73.

Johnston, W. J. and Spekman, R. E. (1982) Industrial Buying Behavior: A Need for an Integrative Approach. *Journal of Business Research*, 10 (2): 135-146.

Jones, J. M. and Zufryden, F. S. (1980) Adding Explanatory Variables to a Consumer Purchase Behavior Model: An Exploratory Study. *Journal of Marketing Research*, 17 (3): 323-334.

Kahn, B. E., Kalwani, M. U. and Morrison, D. G. (1988) Niching Versus Change-of-Pace Brands: Using Purchase Frequencies and Penetration Rates to Infer Brand Positioning. *Journal of Marketing Research*, XXV (November): 384 - 390.

Kamp, B. (2005) Formation and Evolution of Buyer-Supplier Relationships: Conceiving Dynamism in Actor Composition of Business Networks. *Industrial Marketing Management*, 34 (7): 658-668.

Kearns, Z. (2009) *Dirichletvb*. [online] Available from: http://marketing-bulletin.massey.ac.nz/V20/Dirichlet%20vb.xls (Accessed 11 December 2010).

Kearns, Z. and Lewis, T. (2000) An Empirical Comparison of Dirichlet Software. *ANZMAC 2000 Visionary Marketing for the 21st Century: Facing the Challenge*, Gold Coast, Queensland, Australia.

Knight, L., Caldwell, N., Harland, C. and Telgen, J. (2003) Academic Report From the First International Research Study on Public Procurement. *Centre for Research in Strategic Purchasing and Supply*, University of Bath.

Kotler, P. (1991) *Marketing Management*. 7e. Englewood Cliffs, N.J.: Prentice-Hall, Inc.

Kraljic, P. (1983) Purchasing Must Become Supply Management. *Harvard Business Review*, 61 (5): 109-117.

Krause, D. R. and Ellram, L. M. (1997) Success Factors in Supplier Development. *International Journal of Physical Distribution & Logistics Management*, 27 (1): 39-52.

Kuhn, T. S. (1970) *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

Laing, A. and Cotton, S. (1997) Patterns of Inter-Organizational Purchasing, Evolution of Consortia-Based Purchasing Amongst GP Fundholders. *European Journal of Purchasing and Supply Management*, 3 (2): 83-91.

Lakatos, I. (1978) Falsification and the Methodology of Scientific Research Programs. In: Worrall, J. and Currie, G. eds. *The Methodology of Scientific Research Programs: Imre Lakatos Philosophical Papers*. Cambridge: Cambridge University Press: 8-101.

Lakatos, I. (2003) Falsification and the Methodology of Scientific Research Programmes. In: Delanty, G. and Strydom, P. eds. *Philosophies of Social Science*. Maidenhead England: Open University Press: 78-80.

Lam, D. and Mizerski, R. (2009) An Investigation into Gambling Purchases Using the NBD and NBD-Dirichlet Models. *Marketing Letters*, 20 (3): 263-276.

Leckenby, J. D. and Kishi, S. (1984) The Dirichlet Multinomial Distribution as a Magazine Exposure Model. *Journal of Marketing Research*, XXI (February): 100-106.

Lehmann, D. R. and O'Shaughnessy, J. (1974) Difference in Attribute Importance for Different Industrial Products. *Journal of Marketing*, 38 (2): 36-42.

Leong, S. L. (1985) Metatheory and Metamethodology in Marketing: A Lakatosian Reconstruction. *Journal of Marketing*, 49 (Fall): 23-40.

Li, F., Habel, C. and Rungie, C. (2009) Using Polarization to Reveal Systematic Deviations in Dirichlet Loyalty Estimation. *Marketing Bulletin*, 20 (1): 1-15.

Li, S., Madhok, A., Plaschka, G. and Verma, R. (2006) Supplier-Switching Inertia and Competitive Asymmetry: A Demand-Side Perspective. *Decision Sciences*, 37 (4): 547-576.

Lindsay, R. M. and Ehrenberg, A. S. C. (1993) The Design of Replicated Studies. *The American Statistician*, 47 (3): 217-228.

Loader, K. (2010) Is Local Authority Procurement 'Lean'? An Exploration to Determine if 'Lean' Can Provide a Useful Explanation of Practice. *Journal of Purchasing & Supply Management*, 16 (1): 41-50.

London Procurement Programme (2010) *Cardiac Stents*. [online] Available from: http://www.lpp.nhs.uk/page.asp?fldArea=2&fldMenu=5&fldSubMenu=2&fldKey=30 (Accessed 26 November 2010).

Macé, S. and Neslin, S. A. (2004) The Determinants of Pre- and Postpromotion Dips in Sales of Frequently Purchased Goods. *Journal of Marketing Research*, 41 (3): 339-350.

Mattsson, L.-G. (1997) "Relationship Marketing" and the Markets-as-Networks Approach" - A Comparative Analysis of Two Evolving Streams of Research. *Journal of Marketing Management*, 13 (5): 447-461.

Mattsson, L.-G. and Johanson, J. (2006) Discovering Market Networks. *European Journal of Marketing*, 40 (3/4): 259-274.

McCabe, J. and Stern, P. (2009) Stochastic Modelling and Industrial Networks — Complementary Views of Organisational Buyer Behavior. *Journal of the Academy of Marketing Science*, 37 (2): 204-214.

McCay, L. and Jonas, S. (2009) *A Junior Doctor's Guide to the NHS*. [online] Available from: http://group.bmj.com/group/affinity-and-society-publishing/NHS%20Guide.pdf (Accessed 27 September 2010).

McCue, C. and Prier, E. (2006) Using Agency Theory to Model Cooperative Public Purchasing. In: Thai, K. and Piga, G. eds. *Advancing Public Procurement: Practices, Innovation and Knowledge-Sharing*. Boca Raton, FL: Academic Press: 45-71.

McLoughlin, D. and Horan, C. (2002) Markets-as-Networks: Notes on a Unique Understanding. *Journal of Business Research*, 55 (7): 535-543.

McPhee, W. N. (1963) *Formal Theories of Mass Behavior*. New York: Free Press.

Mela, C. F., Jedidi, K. and Bowman, D. (1998) The Long-Term Impact of Promotions on Consumer Stockpiling Behavior. *Journal of Marketing Research*, 35 (2): 250-262.

Miles, M. B. and Huberman, A. M. (1994) *Qualitative Data Analysis: An Expanded Sourcebook*. 2. Newbury Park, CA: Sage.

Mingers, J. (2003) The Place of Statistical Modelling in Management Science: Critical Realism and Multimethodology. *Working Paper No.45*, University of Kent, Canterbury Business School.

Moller, K. E. K. (1994) Interorganizational Marketing Exchange: Metatheoretical Analysis of Current Research Approaches. In: Laurent, G., Lilien, G. L. and Pras, B. eds. *Research Traditions in Marketing*. Dordrecht: Kluwer Academic Publishers: 347-372.

Moller, K. K. E. (1985) Research Strategies in Analysing the Organzational Buying Process. *Journal of Business Research*, 13 (1): 3-17.

Morris, M. H. and Holman, J. L. (1988) Source Loyalty in Organizational Markets: A Dyadic Perspective. *Journal of Business Research*, 16 (2): 117-131.

Morrison, D. G. (1969) Conditional Trend Analysis: A Model That Allows For Nonusers. *Journal of Marketing Research*, 6 (3): 342-346.

Morrison, D. G. and Schmittlein, D. C. (1988) Generalizing the NBD Model for Customer Purchases: What Are the Implications and Is It Worth the Effort? *Journal of Business & Economic Statistics*, 6 (2): 145-159.

Murray, J. G., Rentell, P. G. and Geere, D. (2008) Procurement as a Shared Service in English Local Government. *International Journal of Public Sector Management*, 21 (5): 540-555.

Myers, M. D. and Newman, M. (2007) The Qualitative Interview in IS Research: Examining the Craft. *Information and Organization*, 17 (1): 2-26.

Neslin, S. A., Henderson, C. and Quelch, J. (1985) Consumer Promotions and the Acceleration of Product Purchases. *Marketing Science*, 4 (2): 147-165.

NHS (2009) *About the NHS*. [online] Available from: http://www.nhs.uk/NHSEngland/thenhs/about/Pages/overview.aspx (Accessed 26 September 2010).

NICE (2008) *TA152 Drug-eluting Stents for the Treatment of Coronary Artery Disease*. [online] Available from: http://www.nice.org.uk/nicemedia/live/12013/41262/41262.pdf (Accessed 4 November 2010).

Nollet, J. and Beaulieu, M. (2003) The Development of Group Purchasing: An Empirical Study in the Healthcare Sector. *Journal of Purchasing & Supply Management*, 9 (1): 3-10.

Nollet, J. and Beaulieu, M. (2005) Should an Organisation Join a Purchasing Group. *Supply Chain Management*, 10 (1): 11-17.

Noordewier, T. G., John, G. and Nevin, J. R. (1990) Performance Outcomes of Purchasing Arrangements in Industrial Buyer-Vendor Relationships. *Journal of Marketing*, 54 (4): 80-93.

Norman, H., Romaniuk, J. and Riebe, E. (2005) 100% Brand Loyals Exposed. *The R&D Initiative*, 16.

Office of Government Commerce (2010) *Why is Collaboration Vital?* [online] Available from: http://www.ogc.gov.uk/categories_of_spend_why_is_collaboration_vital.asp (Accessed 28 October 2010).

Ogden, J. A. (2006) Supply Base Reduction: An Empirical Study of Critical Success Factors. *The Journal of Supply Chain Management*, 42 (4): 29-39.

Oliver, R. L. (1999) Whence Consumer Loyalty? *Journal of Marketing*, 63 (4 Special Issue): 33-44.

Owens Swift, C. and Coe, B. J. (1994) Sourcing Preference Scale: Measuring Preferences of Purchasing Managers for Single Sourcing or Multiple Sourcing of Products. *Industrial Marketing Management*, 23 (2): 171-180.

Pare, V. and Dawes, J. (2008) Do all Private Label Brands Exhibit Excess Loyalty? *Proceedings of the ANZMAC 2008 Conference*, Sydney, Australia.

Patterson, J. L., Forker, L. B. and Hanna, J. B. (1999) Supply Chain Consortia: The Rise of Transcendental Buyer-Supplier Relationships. *European Journal of Purchasing and Supply Management*, 5 (2): 85-93.

Peppers, D., Rogers, M. and Dorf, B. (1999) Is Your Company Ready for One-to-One Marketing? *Harvard Business Review*, 77 (1): 151-160.

Peter, J. P. and Olson, J. C. (1983) Is Science Marketing? *Journal of Marketing*, 47 (4): 111-125.

Peter, S. F., Bruce, G. S. H. and Ka Lok, L. (2005) "Counting Your Customers" the Easy Way: An Alternative to the Pareto/NBD Model. *Marketing Science*, 24 (2): 275-284.

Pettigrew, A. M. (1975) The Industrial Purchasing Decision as a Political Process. *European Journal of Marketing*, 9 (1): 4-19.

Phillips, W., Harland, C. and Telgen, J. (2008) Building Public Procurement Capacity and Capability - Academic Report from the Third International

Research Study on Public Procurement. *Centre for Research in Strategic Purchasing and Supply*, University of Bath.

Pickford, C. and Goodhardt, G. (2000) An Empirical Study of Buying Behaviour in an Industrial Market. *Academy of Marketing Annual Conference*, Derby, UK.

Pine, B. J., Peppers, D. and Rogers, M. (1995) Do You Want to Keep Your Customers Forever? *Harvard Business Review*, 1995 (March-April): 103-114.

Popkowski Leszczyc, P. T. L. and Bass, F. M. (1998) Determining the Effects of Observed and Unobserved Heterogeneity on Consumer Brand Choice. *Applied Stochastic Models and Data Analysis*, 14 (2): 95-115.

Preis, M. W. (2003) The Impact of Interpersonal Satisfaction on Repurchase Decisions. *The Journal of Supply Chain Management*, 39 (3): 30-38.

Quayle, M. (2001) Purchasing in the UK and Switzerland:An Empirical Study of Sourcing Decisions. *European Business Review*, 13 (1): 42-59.

Quintens, L., Pauwels, P. and Matthyssens, P. (2006) Global Purchasing:State of the Art and Research Directions. *Journal of Purchasing & Supply Management*, 12 (4): 170-181.

Rauyruen, P. and Miller, K. E. (2007) Relationship Quality as a Predictor of B2B Customer Loyalty. *Journal of Business Research*, 60 (1): 21-31.

Reichheld, F. and Sasser, W. E., Jr. (1990) Zero Defections: Quality Comes to Services. *Harvard Business Review*, 68 (September/October): 105-111.

Ritter, T., Wilkinson, I. and Johnston, W. (2004) Managing in Complex Business Networks. *Industrial Marketing Management*, 33 (3): 175-183.

Robinson, P., Faris, C. and Wind, Y. (1967) *Industrial Buying and Creative Marketing*. Boston, MA: Allyn & Bacon.

Rokkan, A. I. and Buvik, A. (2003) Inter-Firm Cooperation and the Problem of Free Riding Behavior: An Empirical Study of Voluntary Retail Chains. *Journal of Purchasing & Supply Management*, 9 (5 - 6): 247-256.

Rossiter, J. R. (1994) Commentary on Theory or Well-Based Results: Which Comes First? In: Laurent, G., Lilien, G. L. and Pras, B. eds. *Research traditions in marketing*. Boston: Kluwer: 116-122.

Rundle-Thiele, S. and Bennett, R. (2001) A Brand For All Seasons? A Discussion of Brand Loyalty Approaches and Their Applicability For Different Markets. *Journal of Product & Brand Management*, 10 (1): 25-37.

Schmittlein, D. C., Morrison, D. G. and Colombo, R. (1987) Counting Your Customers: Who Are They and What Will They Do Next? *Management Science*, 33 (1): 1-24.

Schmittlein, D. C. and Peterson, R. A. (1994) Customer Base Analysis: An Industrial Purchase Process Application. *Marketing Science*, 13 (1): 41-67.

Schotanus, F. and Telgen, J. (2007) Developing a Typology of Organisational Forms of Cooperative Purchasing. *Journal of Purchasing & Supply Management*, 13 (1): 53-68.

Schotanus, F., Telgen, J. and de Boer, L. (2010) Critical Success Factors for Managing Purchasing Groups. *Journal of Purchasing & Supply Management*, 16 (1): 51-60.

Schunn, C. D. and Wallach, D. (2001) Evaluating Goodness of Fit in Comparison of Models to Data. University of Pittsburgh.

Seth, A., Momaya, K. and Gupta, H. M. (2005) An Exploratory Investigation of Customer Loyalty and Retention in Cellular Mobile Communication. *Journal of Services Research*, Special Issue (December): 173-185.

Sharp, B. and Driesener, C. (2000) The Dirichlet's Buyer Behaviour Assumptions Really Do Matter. *ANZMAC 2000 Visionary Marketing for the 21st Century: Facing the Challenge*, Gold Coast, Queensland, Australia.

Sharp, B., Wright, M. and Goodhardt, G. (2002) Purchase Loyalty is Polarised into either Repertoire or Subscription Patterns. *Australasian Marketing Journal*, 10 (3): 7-20.

Sheth, J. N. (1973) A Model of Industrial Buyer Behaviour. *Journal of Marketing*, 37 (October): 50-56.

Sheth, J. N. (1977) Recent Developments in Organizational Buying Behavior. In: Woodside, A. G., Sheth, J. N. and Bennett, P. D. eds. *Consumer and Industrial Buying Behavior*. New York: Elsevier North-Holland: 17-34.

Sheth, J. N. (2002) The Future of Relationship Marketing. *Journal of Services Marketing*, 16 (7): 590-592.

Shoemaker, R. W., Staelin, R., Kadane, J. B. and Shoaf, F. R. (1977) Relation of Brand Choice to Purchase Frequency. *Journal of Marketing Research*, 14 (4): 458-468.

Silverman, D. (1997) *Interpreting Qualitative Data: Methods for Analysing Talk, Text and Interaction*. 2. London: Sage.

Singh, J., Ehrenberg, A. S. C. and Goodhardt, G. (2008) Measuring Customer Loyalty to Product Variants. *International Journal of Market Research*, 50 (4): 513-532.

Singh, J., Hand, C. and Chen, H. (2009) Differentiation in a Branded Commodity Category: Tapping into Behavioural Data. *Proceedings of ANZMAC 2009 Sustainable Management and Marketing Conference*, Monash University, Melbourne, Australia.

Smith, D. and Taylor, R. (1985) Organisational Decision Making and Industrial Marketing. *European Journal of Marketing*, 19 (7): 56-71.

Soderlund, M., Vilgon, M. and Gunnarsson, J. (2001) Predicting Purchasing Behavior on Business-to-Business Markets. *European Journal of Marketing*, 35 (1/2): 168-181.

Spiteri, J. M. and Dion, P. A. (2004) Customer Value, Overall Satisfaction, End-User Loyalty, and Market Performance in Detail Intensive Industries. *Industrial Marketing Management*, 33 (8): 675-687.

Stern, P. (1994) *Patterns of Prescribing*, PhD Thesis, University of London.

Stern, P. and Ehrenberg, A. S. C. (1995) The Market Performance of Pharmaceutical Brands. *Marketing and Research Today*, (November): 285-292.

Stern, P. and Hammond, K. (2004) The Relationship Between Customer Loyalty and Purchase Incidence. *Marketing Letters*, 15 (1): 5-19.

Tella, E. and Virolainen, V.-M. (2005) Motives Behind Purchasing Consortia. *International Journal of Production Economics*, 93-94, 161-168.

Turnbull, P., Ford, D. and Cunningham, M. (1996) Interaction, Relationships and Networks in Business Markets; An Evolving Perspective. *Journal of Business and Industrial Marketing*, 11 (3/4): 44-62.

Uncles, M., Ehrenberg, A. and Hammond, K. (1995) Patterns of Buyer Behavior: Regularities, Models, and Extensions. *Marketing Science*, 14 (3): G71-G78.

Uncles, M. and Kwok, S. (2003) Toothpaste Purchasing in China: Patterns of Buyer Behaviour. *Proceedings of the ANZMAC 2003 Conference*, Adelaide, Australia.

Uncles, M. and Laurent, G. (1997) Editorial. *International Journal of Research in Marketing*, 14 (5): 399-404.

Uncles, M. D. (1989) BUYER: Buyer Behaviour Software. *CMaC Report*, London Business School.

Uncles, M. D., Dowling, G. R. and Hammond, K. (2003) Customer Loyalty and Customer Loyalty Programs. *Journal of Consumer Marketing*, 20 (4): 294-316.

Uncles, M. D. and Ehrenberg, A. S. C. (1990) Industrial Buying Behaviour: Aviation Fuel Contracts. *International Journal of Research in Marketing*, 7 (1): 57-68.

Vereecke, A. and Muylle, S. (2006) Performance Improvement Through Supply Chain Collaboration in Europe. *International Journal of Operations and Production Management*, 26 (11): 1176-1198.

Vigoroso, M. (1998) Buying Consortiums Suit Some, Not All. *Purchasing*, 125 (2): 18-19.

Vyas, N. and Woodside, A. G. (1984) An Inductive Model of Industrial Supplier Choice Processes. *The Journal of Marketing*, 48 (1): 30-45.

Wagner, U. and Taudes, A. (1986) A Multivariate Polya Model of Brand Choice and Purchase Incidence. *Marketing Science*, 5 (3, Summer): 219-244.

Walker, H., Harland, C., Knight, L., Uden, C. and Forrest, S. (2008) Reflections on Longitudinal Action Research with the English National Health Service. *Journal of Purchasing & Supply Management*, 14 (2): 136-145.

Walker, H., Knight, L. and Harland, C. (2006) Outsourced Services and 'Imbalanced' Supply Markets. *European Management Journal*, 24 (1): 95-105.

Webster, F. E., Jr. and Wind, Y. (1972) A General Model for Understanding Organisational Buying Behaviour. *Journal of Marketing*, 36 (April): 12-19.

Welch, C. and Wilkinson, I. (2002) Idea Logics and Network Theory in Business Marketing. *Journal of Business to Business Marketing*, 8 (3): 27-48.

Wensley, R. (1995) A Critical Review of Research in Marketing. *British Journal of Management*, 6 (December): S63-S82.

Wilkinson, I. F. and Young, L. C. (2005) Towards a Normative Theory of Normative Marketing Theories. *Marketing Theory*, 5 (4): 363-396.

Wilson, D. F. (2000) Why Divide Consumer and Organizational Buyer Behaviour? *European Journal of Marketing*, 34 (7): 780-796.

Wind, Y. (1970) Industrial Source Loyalty. *Journal of Marketing Research*, 7 (4): 450-457.

Wind, Y. J. (2006) Blurring the Lines: Is There a Need to Rethink Industrial Marketing? *Journal of Business and Industrial Marketing*, 21 (7): 474-481.

Wright, M. and Kearns, Z. (1998) Progress in Marketing Knowledge. *Journal of Empirical Generalisations in Marketing Science*, 3 (1).

Wright, M., Sharp, A. and Sharp, B. (2002) Market Statistics for the Dirichlet Model: Using the Juster Scale to Replace Panel Data. *International Journal of Research in Marketing*, 19 (1): 81-90.

Yanamandram, V. and White, L. (2006) Switching Barriers in Business-to-Business Services: A Qualitative Study. *International Journal of Service Industry Management*, 17 (2): 158-192.

Yim, C. K. B. and Kannan, P. K. (1999) Consumer Behavioral Loyalty: A Segmentation Model and Analysis. *Journal of Business Research*, 44 (2): 75-92.

Young, L. and Denize, S. (1995) A Concept of Commitment: Alternative Views of Relational Continuity in Business Service Relationships. *Journal of Business & Industrial Marketing*, 10 (5): 22-37.